DRAFT

Follow-up Report on the Schedule for the BTeV Project

The BTeV Project and Collaboration

May 24, 2004

(This page intentionally left blank)

Follow-up Report on the Schedule for the BTeV Project

TABLE OF CONTENTS

1 INTRODUCTION

A Lehman CD-1 Review of the BTeV Project was conducted at Fermilab from April 27-30, 2004. The summary report states:

"The Committee supports the proposed technical scope and the cost range presented."

The Committee, however, had questions on the schedule. They recommended that (BTeV):

"Develop a schedule and funding profile for BTeV, such that the desired scientific capabilities are obtained while ensuring that the scientific output is competitive and timely. Provide revised plans to DOE as soon as possible, to support the CD-1 decision process.''

In following up the results of the review, Dr. Robin Staffin, Head of the Office of High Energy Physics, wrote

"*Based on the conclusion from the Lehman review, a consultation with the HEPAP and P5 chairs, and the recommendations from OHEP annual program review consultants, I would like to ask the laboratory to provide revised schedule and funding plans and their associated comparisons for the timeline of the physics reach between BTeV and LHCb.*

Two different scenarios we discussed as possibilities are:

(1) The Laboratory and BTeV collaboration would present to the DOE a new schedule that is generally based on the technical scope and funding profile that was presented to the Lehman review. This schedule should include sufficient float to insure completion of the project. Estimates from the review team indicate that this will require an additional 6 to 12 months in the duration of the project. The Laboratory and BTeV collaboration may include in this scenario a stage at which physics operation would start with an incomplete detector before completion of the project.

(2) The Laboratory and the BTeV collaboration would present a new plan that involves more financial and possibly more manpower resources in the next few years (FY 05 to FY07) in order to preserve the FY09 completion date for the full experiment.

I would like to receive the revised schedule and funding profile plans for the first scenario before June 15."

In this document, we address the first part of the above charge. We describe the changes that have been made in the BTeV Project to permit us to develop a schedule that is highly likely to be achieved within the constraints of the current funding guidance from Fermilab. To achieve this, we have adopted a "staged installation" approach, which we will show also preserves the timeliness and competitiveness of BTeV relative to its competition, the LHCb experiment.

The second part of the charge will be the subject of another document.

The organization of this document is as follows:

• In Section 2, we describe changes we have made in the BTeV Project and schedule to satisfy the recommendation. These include installing the detector in two stages, in a way that maintains its physics competitiveness and timeliness, the reallocation of resources within the project to improve the schedule, the incorporation of suggestions from the reviewers and insights gained by further investigation into areas of their concern, and the effect of a complete review and scrubbing of the schedule to remove unnecessary constraints and expose hidden contingencies;

• Section 3 presents the argument that the Staged detector's physics output will be "competitive and timely;"

• Section 4 describes the methodology that we employed to carry out our scheduling activity. The "staging" scenario introduces complications that require precise definition of how floats are determined.

• Section 5 discusses installation issues with the new schedule;

• Section 6 presents the new schedule for the whole project with summary information on when each detector project is "ready to install" as compared to when it is "needed by." We also discuss the overall schedule of activities in the C0 Assembly area, which must be organized to avoid interferences between subprojects. The revised cost and cost profile are shown. The overall project Critical Path is shown. We also discuss a high-level risk analysis with mitigations and work-arounds;

• Section 7 describes the new cost and schedule for each of the 13 subprojects using a standard template.

2 CHANGES TO THE SCHEDULE SINCE THE CD-1 REVIEW

This section describes the changes that we have implemented since the CD-1 Review to make a schedule that is highly likely to be achieved.

2.1 Staged Installation of the Detector

The new schedule is based on installing the detector in two stages.

- The first stage of the installation occurs at the same time as the "full installation" presented at the CD-1 review, a four month period starting in early August 2009. The C0 Low Beta IR will be installed in this period. However, we will install only ½ of the electromagnetic calorimeter crystals, about 2/3 of the charged-particle tracking and muon detectors, and ½ of the data acquisition and trigger system capacity. This installation stage would complete at the end of November 2009 and would be immediately followed by a commissioning and data-taking run that would end in early July of 2010. At this stage, the BTeV Detector will have about 75% of the reach of the full detector for B decays to all charged particles and about 50% of the total reach for B decays which contain photons. The BTeV detector will be comparable to LHCb for all-charged decays and already superior for decays with photons. This is discussed in section 3.
- The second stage of installation will begin in July of 2010 and last for twelve weeks. The remaining portion of the crystal calorimeter will be installed along with the remaining tracking detectors, data acquisition, and trigger capability. This will give the BTeV detector its full capability for final states with photons and, with the complete trigger and data-acquisition systems, the ability to collect, reconstruct, and study directly produced charmed particles, an important but secondary goal of BTeV. At the end of this stage, operations will resume with the full BTeV detector and will continue for several years with at most short shutdowns for machine and detector maintenance. The full detector's physics reach in each calendar year of running will be comparable to or superior to LHCb in B decays to all-charged final states, vastly superior in B decays to states containing photons, and significantly better for directly produced charm.

This "staged installation" addresses both major issues in the Lehman Committee CD-1 recommendation. The new schedule has much greater schedule contingency and is highly likely to be achieved because the project has 6-10 months more to prepare the equipment for the second installation stage. The funding that does not become available until October of 2008 can be applied aggressively, through options taken on contracts in FY08 and before, to provide the needed equipment on time. Moreover, the current plan provides 30 weeks for installation rather than 16 in response to another of the CD-1 reviewers' concerns. Finally, because of the order in which detector components are installed, the partial detector that comes on at the end of the first installation stage is able to compete with LHCb in main areas of overlap and to have a significant part of its unique ability to study B decays with neutrals.

The staged BTeV Detector is shown in Figure 1. A detailed description of the staged components is given below.

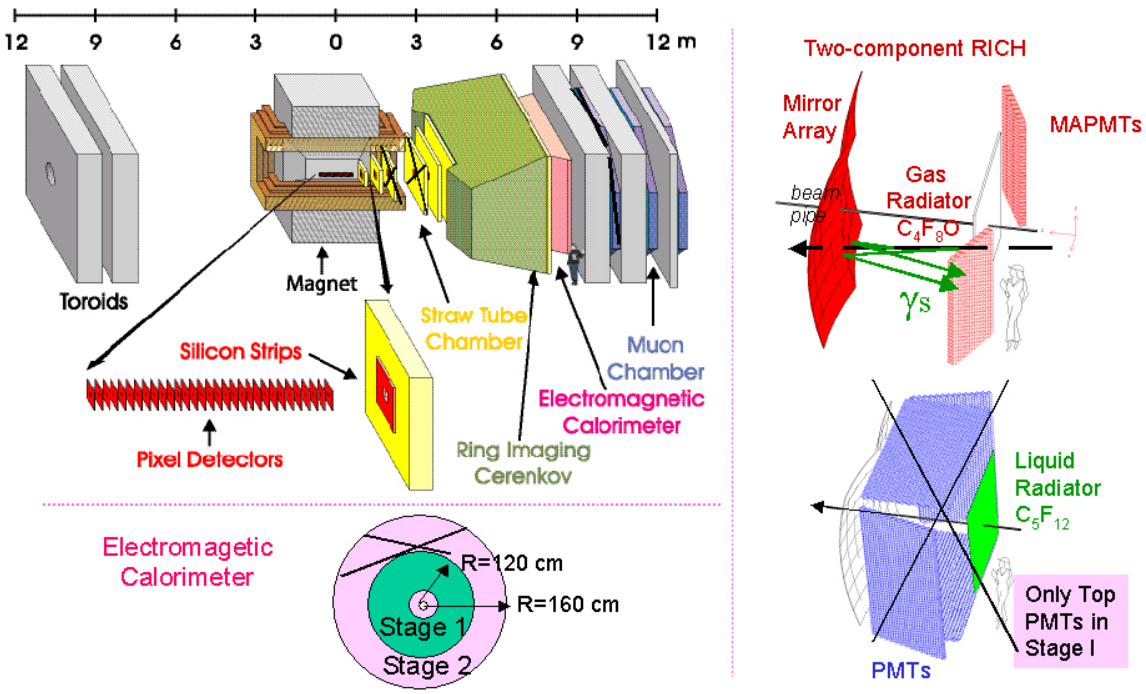


Figure 1: A schematic of the BTeV detector. The components that will be installed in the second installation phase are indicated with crosses.

2.1.1 Detailed description of Staged Installation

The goal of the Stage 1 installation is to provide high luminosity collisions in C0 and a detector capable of triggering and recording to archival storage for subsequent physics analysis all interesting B decays to all charged final states and about half the rate of B decays with photons in the final state as in the full detector. This will give BTeV a physics reach that is superior to LHCb for all-charged decay modes and already superior even for decay modes with photons, but with only about 50-60% of BTeV's ultimate capability.

This is achieved as follows:

1. The full IR will be installed. This is necessary to obtain collisions at high luminosity in C0. All components of the C0 IR are installed outside the C0 Collision Hall in the tunnel sections upstream and downstream of it. The interference between the IR installation and the BTeV Detector installation is minimal.

2. The full Pixel Detector is installed. During the review, the possibility of installing a partially loaded Pixel Detector was discussed in case the full detector could not be ready in time. This would require installing the partial detector, removing it and transporting it back to SiDet, installing the missing stations, retesting the vacuum system and electrical connections, moving it back to C0, reinstalling it, hooking it back up to utilities and the data acquisition/trigger system, and checking out all connections and the establishing the vacuum again. Given the delicate nature of the detector, this option would add substantial technical and schedule risk to the project. Instead, we have reallocated funds within the BTeV project to increase the Pixel Detector budget by approximately $300K in FY05 and $1400K in FY06 to ensure that the full detector can be ready well before it is needed for installation in the fall of 2009. The schedule contingency is now greater than 10 months and is discussed in detail in section 6b.
3. Only a portion of the forward charged particle tracking system is installed. We plan to install 5 of the Forward Straw Tracker stations, numbers 1, 2, 5, 6, and 7. We will also install 4 of the Forward Silicon Microstrip stations, numbers 1, 2, 5 and 6. This reduces the number of forward tracker devices that have to be installed in this first period from 14 to 9. The choice of devices to omit has been influenced by physics concerns and by the desire to leave the installed devices in place during the second stage installation. The devices in stations 3 and 4 can be installed in Stage 2 without disturbing any of the devices that were installed in Stage 1. Station 7 of the Forward Microstrip Tracker is omitted in Stage 1 because it might interfere with work on the EMCAL in Stage 2. It will be installed after the EMCAL work is done. Of all the forward tracking elements, it contributes the least to the B physics reach of BTeV. The role of the missing stations is to provide extra tracking redundancy especially in the unlikely (according to our extensive aging tests) but possible scenario in which radiation damage reduces the efficiency near the beam. This will not be a problem in the early years of running.
4. Only ½ of the EMCAL lead tungstate crystals are installed in Stage 1. This addresses uncertainties in the delivery of the crystals in light of problems with the CMS crystal production. This issue is discussed in section 6d. However, even under pessimistic assumptions, at least half the crystals should be ready well in advance of the first installation period. In BTeV, each crystal is supported independently in an egg crate type arrangement. We can take advantage of this to place the crystals in an arrangement that maximizes the physics reach for the number that we install in Stage 1. Simulation has shown this to be an annulus extending from R= 40 cm to R= 120 cm. The impact of the loss of crystals at radii below 40 cm is less because our efficiency there is lower (due to overlapping showers) and at radii above 120 cm the rate of signal photons is falling off rapidly. The signal yield is shown to be about 60% for the key final states.

   In the plan presented at the CD-1 review, the calorimeter support was installed in the C0 Collision Hall during a shutdown in 2008. It was loaded with whatever crystals that had already been delivered by the spring of 2008. All crystals arriving after that had to be installed into the support during shutdowns. In the new plan, we will construct the calorimeter support in the C0 Assembly Area but defer the installation in the Collision Hall until the beginning of the August 2009 shutdown so we can use all the time to load it with crystals. We expect that we will have at least 5000 crystals, the goal for the phase 1 installation, preinstalled in the support by then. If we have additional crystals available at the start of the shutdown, we can install them in place any time during 28 weeks of the shutdown. lation period in August of 2009. We estimate that we can install crystals in C0 at a rate of about 100/day (see section 6d). This is based on our own studies and checked against the KTeV CsI crystal installation experience. With the staged installation providing 30 weeks, there is now adequate schedule contingency on the installation.

5. We will install 2 stations of the Muon Detector, the second and third. They are installed downstream of the toroid, so are the easiest to install. We also plan to install the support structure in the toroid for station 1. With stations 2 and 3 only, one can achieve nearly full efficiency and rejection for offline muon analysis but one cannot commission or operate the Muon Trigger. The muon trigger is used primarily to cross check the performance of the Pixel Trigger during steady state running. In fact, we do not commit to having the Muon Trigger ready for Stage 1. However, we will also install one octant of station 1 which will allow us to completely study the Muon Trigger offline and commission it on real data during the off period for Stage 2 installation so it will be ready when we resume operation.
6. All mechanical components of the Ring Imaging Cherenkov detector (RICH) will be installed. This includes the containment vessel for the gas radiator and the liquid radiator. The full MAPMT array will be installed providing the full particle identification capability of the gas radiator. Only the upper of the four PMT panels that detect photons for the liquid radiator will be installed. That part is the most difficult to install because access is impeded by the "expansion volume" that sits above it. The remainder of the tubes will be installed during the 2010 shutdown. All MAPMTs and PMTs are installed on panels and completely tested outside the Collision Hall. Installation issues are not the reason for staging. The staging of the PMTs allows us to free up money to buy all the RICH electronics early and is necessary to implement the MAPMT readout of the gas radiator with adequate schedule contingency.
7. The Trigger and DAQ are staged purely for budgetary reasons. Theses systems are based on commercial CPUs and networking equipment whose price/performance ratio is rapidly declining. These systems all reside in the BTeV counting room so their installation is not affected by availability of access to the Collision Hall. For these reasons, they are good candidates for staging. The trigger and DAQ are also required to have 50% excess capacity, another reason for staging. Finally, the input to the Level 2 and 3 systems can be controlled by "cuts" or selection criteria that can be controlled at the factor of two level with very little loss of B physics. In fact, more than 1/2 of the Level 2/3 and DAQ capacity is devoted to secondary physics goals such as charm and special calibration data that can be reduced in the first running period. We plan to have

four out of eight Level 1 highways fully functioning by November of ’09 and are committed to have the remaining four by July 2010 (although we have a good probability of having another two by January of 2010 and the final two in February of 2010 so they can be employed in the first run). For Level 2/3 and DAQ, half the capacity is required in January of 2010 and the rest by July 2010. In that way, the full trigger and DAQ will be available well before the resumption of running after the Stage 2 installation is complete.

In the Stage 2 installation period, we will install in the C0 Collision Hall the remaining 5000 or fewer lead tungstate crystals; two full stations of forward tracker and the 7th station of silicon microstrip; station 1 of the Muon System; and the three pre-assembled and tested panels of the Liquid RICH. In the BTeV Trigger Room on the third floor of the C0 Control Room we will install the remaining elements of the Trigger and DAQ system, including the Muon Trigger. Based on current delivery schedules, this should be done before the July 2010 shutdown. Testing of the Muon Trigger can be accomplished by feeding it data, through its input buffer, from the fully instrumented (all three stations) octant.

2.1.2 Further issues with respect to the Staged Installation

The timing and length of Tevatron shutdowns beginning in August 2009 and through the end of 2010 will be determined by BTeV installation, commissioning, and physics needs. Thus, if more equipment is available for installation in ’09, it should be possible to extend the shutdown to install if it turned out not to impact our competitiveness with LHCb (for example, due to delays in their schedule). Similarly, if the shutdown in 2010 needed to be extended because it took a little longer to complete the installation, this would not result in a scheduling problem.

It is worth noting that many of the subsystems that are scheduled to be installed in Stage 2 could be ready earlier and we will continue to manage to the most aggressive schedule that we can, given our budget constraints.

2.2 Reallocation of Resources within the Project

The reviewers expressed concern over the schedules of several of the subprojects. Some of these subproject schedules were very sensitive to the level of funding in the first year of the project. We also now have changed the schedule so that some detectors do not have to be complete in FY’09. In response, we have restructured the funding in FY05, FY06, and FY07 to create more schedule contingency. While dollar value of this restructuring is minor on the scale of the full project it has high impact on three of the subprojects.

Here are some examples of this. Funds have been added to the Pixel Detector in FY’05 ($300K) and in FY’06 ($1.4M). These have produced ½ of the overall 6 month speedup in the schedule. About $100K has been added for one FTE to start DAQ design in 2005 and this has advanced the schedule by 9 months. The deferral of the purchase of the Liquid RICH PMTs to FY'08 from FY'07 has permitted us to place the electronics purchase order a year earlier and that completes the RICH electronics well in advance of when they are needed to instrument the Gas RICH.

2.3 Adoption of Explicit Suggestions and Recommendations from the Review

The committee made some explicit suggestions on how to increase the project schedule contingency. For example, the Pixel Detector team was advised to handle prototype and production procurements as single staged acquisitions with an option to continue after the prototype run succeeds. This has reduced the Pixel Schedule by 6 months. The reviewers also recommended that we increase the total time for the hybridization contract by 3 months based on the experience of ATLAS and we have likewise made this change.

2.4 Effect of More Work on Specific Issues Raised in the Review

The reviewers raised specific concerns that we are addressing. We have been in contact with CMS management to understand the possible impact their problems in getting lead tungstate crystals might have on BTeV. Their plan is to try to increase world-wide lead tungstate crystal capacity by a large amount to meet their schedule. If they succeed in doing this, then we can meet our current schedule easily but the first crystals will be delivered somewhat later. This is discussed below in section 6d.

2.5 Additional Resources from Fermilab to Speed up the Project

Fermilab has provided additional technical resources to work on conceptual design efforts in the first phase of C0 outfitting and IR. Support has now been provided to ensure that when CD2/3a approval has been obtained that the C0 Outfitting Phase 1 design work will be completed on schedule. Additional engineering support has been provided to the C0 IR team in the Fermilab Technical Division. This has enabled them to begin a design study of the spool assembly process, the knowledge gained from which has allowed them to advance their schedule.

2.6 More Total Time for Installation

Our schedule for installation in 2009 C0 was based on a bottoms up estimate that we checked against a somewhat larger project – the installation of KTeV in 1996/7. The reviewers expressed some skepticism about this schedule, which had only 16 weeks of access to the C0 Collision Hall. The new staged schedule has 30 weeks between the 2009 and 2010 shutdowns. This is longer than the KTeV installation period and, unlike them, BTeV will already have installed all the large detector components during shorter shutdowns from 2006 to 2008. The issue of possible delays in lead tungstate production and the length of time it takes to install the crystals is specifically addressed and resolved by the staging plan.

2.7 Scrubbing of the Schedule

Our schedule as presented at the CD-1 review had several instances of large hidden schedule contingency. In some cases, reviewers observed these as well. We have now removed these and display them as explicit schedule contingency. All subprojects are now using a uniform and well-defined algorithm for determining schedule contingency. As an example of this hidden contingency from the CD-1 review, the August 1, 2009 shutdown date that defines when many components must be ready for installation was translated into June 1 on many projects. Some projects decided that they needed to be ready one month before June 1 and calculated schedule contingency with respect to May 1, 2009.

Some subprojects calculated their schedule contingency relative to when their detectors needed to be available for installation while others included the installation. This is now handled in a uniform and well defined manner throughout the project. The schedule contingency for the “construction” of components is judged relative to a 4 –5 year construction period. The schedule contingency on the installation of those components into C0 is calculated for the much shorter installation period separately.

Because of these problems and the additional complexities of the Staged Schedule, we have developed a new consistent methodology for describing the project schedule, computing critical paths and floats, and showing where schedule contingency might be needed and how it could be deployed. This is described in section 4 below.

3 PHYSICS CAPABILITY, COMPETITIVENESS, AND TIMELINESS OF THE STAGED DETECTOR

3.1 Executive Summary

The HEPAP subpanel P5 recommended construction of BTeV based on its ability to be the best heavy flavor experiment in the period 2009-2014, or longer. They said: "The strength of the BTeV experiment comes from the combination of its vertex trigger with precision mass measurements for both charged and neutral decay modes and excellent particle identification capabilities."

We are now planning to install a staged detector for the first seven months of operation, followed by a short shutdown to install the rest of the detector. This results from the desire to create a schedule with a good fraction of a year of schedule contingency for the major systems consistent with the present funding profile. The staged detector will maintain the full pixel detector and enough of the trigger system to allow triggering on all B decays at a rate about 5 times that of LHCb. The tracking system will be complete except for some downstream layers that are mostly needed for additional redundancy. For charged decay modes, the ones for which LHCb is most competitive, the product of trigger, tracking, and flavor tagging efficiencies for the staged detector will be about 75% that of the full detector.

Only half of the electromagnetic calorimeter will be installed for Stage I. As a result, the efficiencies for neutral decay modes in the first running period for BTeV will be typically about 60% of that with the full detector. Since LHCb does not have a crystal calorimeter at all, the staged BTeV detector will far outperform LHCb for these modes. The other staged elements will principally reduce the trigger rate for charm physics, not for the most important physics goals of BTeV.

To reach a given error on the CP-violating parameter γ from $B_s \to D_s^+ K^-$, it will take half as much integrated luminosity with BTeV Stage I as with LHCb. BTeV will get over twice as much integrated luminosity, in the 10-month running year at the Tevatron, as LHCb is expecting to get in the 5.3-month running year with protons at the LHC. The measurement of the CP violating parameter α with BTeV stage I using the decay mode $B \to \rho\pi$ will dominate that of LHCb even with the smaller crystal calorimeter. BTeV stage I will be able to write about 5 times as many B mesons as LHCb to archival storage. In BTeV, these will be recorded without regard to specific decay modes, which will be a great advantage in looking for surprises, as the B-factories are able to do now. After the full BTeV detector is installed, its rate for observing CP violating decay modes containing neutral particles will double.

LHCb is likely to get some data before BTeV turns on. However, since there will have been data taken by the e^+e^- B-factories on B^o and B^- decays and CDF and D0 on B_s decays, the first year or two of LHCb running, that will have a relatively low integrated luminosity, will be used, most likely, to merely catch up to the level of accuracy attained by these older experiments.

In summary, BTeV Stage I will maintain the advantages over LHCb that led to its strong approval by the Fermilab Physics Advisory Committee and P5. For the charged modes, in which LHCb is most competitive, Stage I will represent a 75% efficiency relative to full BTeV. For the neutral modes, in which BTeV will dominate LHCb, the efficiency of the staged detector will be about 60% when flavor tagging is not required and 45% when it is. As soon as the BTeV collaboration is able to reconstruct data and do the physics analysis, a challenging process that will take some time for any experiment, it will be leading the world in most important B physics modes and it will be completely dominant in several key areas.

3.2 Introduction

The BTeV project consists of the Detector, the Interaction Region (IR) and the outfitting of the C0 hall. The detector will be installed in two stages in order to ensure enough flexibility in its schedule to guarantee that it will be installed on schedule. The IR and outfitting are planned to be completed in time for the Stage I detector.

The BTeV detector is described in detail in the BTeV Technical Design Report (TDR)[1]. Briefly, it is a forward spectrometer following the anti-proton direction in the C0 collision hall of the Tevatron collider. It includes a pixel detector, embedded in the machine vacuum, inside of a dipole magnet, whose main function is to measure very precisely the positions of charged tracks and send this information to the trigger which is implemented to detect the presence of decay vertices of b and c quarks. The charged tracks then traverse a series of detection planes that measure their momenta. This forward tracking system consists of silicon strips close to the beam line and straw tube based wire chambers at larger distances. There is a Ring Imaging Cherenkov Detector, (RICH) to identify charged particles, an electromagnetic calorimeter that detects photons and electrons and a system to identify muons using a toroidal magnet. The primary trigger is based on detecting detached heavy quark vertices. There is another trigger for dimuon events that is used mainly to evaluate efficiencies. There is also a high capacity data acquisition system.

In order to ensure that we can take physics quality data at the end of 2009, we have developed a "staged" construction and installation plan. The staging will be done in two steps. The installation of the first stage detector will start on Aug. 1, 2009.

We plan to install the following components for the Stage I detector:

- The complete pixel detector;
- The gas radiator RICH system, the liquid radiator with 25% of the readout photomultiplier tubes;
- One half of the $PbWO_4$ crystals in the EM calorimeter;
- Two out of the three stations of Muon detector;
- Five of the seven Forward Straw Tracker stations, numbers 1, 2, 5, 6, and 7.
- Four of the seven Forward Silicon Microstrip stations, numbers 1, 2, 5 and 6.
- The detached vertex trigger and one half of the trigger and DAQ throughput.

The parts of the detector that we do not commit to in the first stage are

- 75% of the photomultiplier tubes used for the Ring Images of Cherenkov photons generated in the liquid radiator;
- 50% of the $PbWO_4$ crystals for the EM calorimeter;
- One Muon tracking station and the dimuon trigger;
- 50% of the trigger and DAQ capabilities;
- The Straw Tracking stations 3 and 4 and the Silicon Microstrip stations 3, 4 and 7.

We are committed to installing these parts of the detector in the second installation stage starting July 1, 2010.

In this note we compare the physics reach of BTeV Stage I and Stage II to that of LHCb as a function of time. The physics case for BTeV can be found on the web[2].

3.3 General Comparisons with LHCb

LHCb[3] is an experiment planned for the LHC with almost the same physics goals as BTeV. BTeV is at least as good as LHCb in all areas and it is far superior in some very important areas. Both experiments intend to run at a luminosity of $2x10^{32}$ $cm^{-2}s^{-1}$. There are several inherent advantages and disadvantages that LHCb has compared with BTeV. The issues that favor LHCb are:

- The b production cross-section is expected to be about five times larger at the LHC than at the Tevatron, while the total cross-section is only 1.6 times as large.
- The number of interactions per bunch crossing is expected to be about 3 times lower at the LHC than at the Tevatron.

The issues that favor BTeV are:

- BTeV is designed to have the vertex detector in the magnetic field, thus allowing the rejection of low momentum tracks at the trigger level. Low momentum tracks are more susceptible to multiple scattering which can cause false detached vertices leading to poor background rejection in the trigger[4] .
- BTeV is designed with a high quality $PbWO_4$ electromagnetic calorimeter, far superior to that of LHCb, that provides high resolution and acceptance for interesting final states with γ's, π^{o}'s, and $\eta^{(\prime)}$'s [5] .
- The LHCb data acquisition system is designed to output 200 Hz of b decays, while BTeV is designed for larger output bandwidth of 1,000 Hz of b's and 1,000 Hz of charm, and an additional 2000 Hz for contingency, calibration events, and other physics. Therefore, BTeV has access to a much wider range of heavy quark decays.
- The running schedule at the LHC is estimated to be only 160 days per calendar year after initial shakedown. This does not include any Heavy Ion running which would subtract at least 28 days from the total. At LHCb's running luminosity of $2x10^{32}cm^{-2}s^{-1}$, the integrated luminosity per calendar year[6] is expected to be 0.8 fb^{-1} . BTeV expects to run 10 calendar months and should integrate 1.6 fb^{-1} in the steady state[7].
- BTeV has to cover a smaller range of particle momenta. The seven times larger beam energy at the LHC makes the momentum range of particles that need to be tracked and identified much larger and therefore more difficult. The larger energy also causes a large increase in track multiplicity per event, which makes pattern recognition and triggering more difficult.
- The interaction region at the Tevatron is six times longer along the beam direction than at LHC (σ_z = 5 cm), which allows BTeV to be able to accept collisions with a mean of up to six interactions per crossing, since the interactions are well separated in z. LHCb tries to veto crossings with more than one interaction.
- The short bunch spacing at the LHC, 25 ns, has serious negative effects on all their detector subsystems. There are occupancy problems if the sub-detector integration times are long. This can be avoided by having short integration times, but that markedly increases the electronics noise. For example, in a silicon

detector these considerations make first level detached vertex triggering more difficult than at the Tevatron[8] .

- Use of a detached vertex trigger at Level 1 allows for an extensive charm physics program absent in LHCb. It also accepts a more general collection of b events, which are less oriented towards particular final states.
- LHCb must tolerate far higher beam currents and their associated backgrounds through their detector that support luminosities of 10^{34} $cm^{-2}s^{-1}$ in other interactions regions.

We have compensated for LHCb's initial advantages in b cross-section due their higher center-of-mass energy. In fact, the high energy actually works in many ways as a disadvantage. For example, LHCb needs two RICH counters to cover the momentum range in their one arm. Particle identification and other considerations force LHCb to be longer than BTeV, in fact about twice as long. As a result, LHCb's transverse area is four times that of BTeV, in order to cover the same solid angle. It is expensive to instrument all of this real estate with high quality particle detectors. Thus, the total cost for LHCb based only on instrumented area, (a naive assumption) would be four times the total cost for BTeV.

For our Proposal and Proposal Update, we compared our physics reach with that of LHCb as documented in their Technical Design Report[9] and a B Physics at the LHC document[10]. Recently, however, they have extensively redesigned their detector and now call it "LHCb Light"[11],[12] The changes were prompted at least partially by them not using the proper Pythia generator (they were using version 5.7 rather than 6.2, while BTeV always used 6.2) and their realization that they had too much material in the upstream part of the
detector. The changes include reducing the number of silicon strip detectors in their vertex detector from 25 to 21 and lowering the silicon thickness from 300 to 220 μm, reducing the number of tracking stations, removing the magnet shielding plate, thus allowing field on the vertex detector and RICH-1, and adding a high p_t only trigger which helps primarily on $B \rightarrow h^+h^-$ final states.

While LHCb has done some studies of their physics sensitivities in this new configuration, they are not as extensive as before and in some cases they computed efficiencies in this new configuration but do not have enough background events do determine their background; furthermore our experience is that you may have to drastically retune your signal selections when you find out about the backgrounds you have to fight, and this could materially lower their efficiencies. We are particularly concerned that in "LHCb Light" their ghost track rate on tracks going through the entire spectrometer is between 3-8%, depending on p_t, while the BTeV ghost rate is less than 1% for similar tracking efficiency of 95%.

3.4 Assumptions About Schedules

Besides the inherent differences in the two experiments, the machine commissioning phases will be quite different. BTeV is operating at an existing machine and the period to make useful luminosity should be quite short, on the order of a month, while LHCb will be born at a brand new accelerator.

Let us first consider the steady state luminosity for LHCb. Collier gives his expectations of the steady state running of the LHC[13] after the first year or two of shake down. The yearly physics running of LHC is limited to 160 days minus that used for heavy ion running that subtracts at least another 21 days. Using Collier's efficiency factors and an initial starting luminosity of $2.8x10^{32}cm^{-2}s^{-1}$, LHCb will integrate 0.8 fb^{-1} in the steady state[14].

BTeV is expected to run for 10 months a year, about a factor of two more running time than LHCb. In steady state, BTeV will accumulate 1.6 fb^{-1} per year[15] .

The official LHC schedule at the time of this writing is to have some beam starting in April of 2007 with a short runs to the experiments over the next year. The initial bunch spacing will be 75 ns, which causes a problem for LHCb because of multiple interactions per crossing and, in addition, they need special setups to get useful luminosity[16]. Thus, they will collect about 0.1 fb^{-1} in 2007. Starting in April 2008, the running will shift to 25 ns bunch spacing, the luminosity will increase and LHCb could optimistically accumulate three-quarters of year of steady running or 0.6 fb^{-1}. In 2009 they would accumulate 0.8 fb^{-1}.

This schedule however is aggressive and has no "float." To compare with the schedule BTeV is encouraged to make it would be reasonable to add one year of float to the LHC schedule. (Of course, even if they met this schedule they would be a great success.) Here LHCb accumulates 0.1 fb^{-1} in 2008, 0.6 fb^{-1} in 2009 and 0.8 fb^{-1} in 2010 and beyond. Since we do not know which of the these schedules will actually occur we will compare with both of them.

BTeV installs the interaction region magnets and the Stage I detector in 2009 and has a month of running to commission the interaction region. The BTeV schedule mandates 6 months of running with the Stage I detector in 2010, accumulating 1 fb^{-1} followed by a shutdown and then another 3 months of running with the Stage II detector, accumulating 0.5 fb^{-1}.

In the case of both LHCb and BTeV we have not included any time for detector "shakedown," which is assumed to be the same for both experiments and should therefore add a roughly similar amount to both timelines[17] .

To give a general idea of one key difference between the two experiments, we show the total number of b anti-b events written to "tape" in Figure 2. For purposes of this example we derated the BTeV Stage I detector by an overall factor of two with respect to the Stage II system. We see that by the end of 2010 BTeV will have between a factor of two and a factor of three more accumulated events than LHCb. The large difference in the number of accumulated events is due to two facts: first of all, BTeV is designed to write more than five times as many b-events to "tape," and BTeV runs twice as long each year at the same luminosity. *The large number of events becomes important when new modes are thought of that will elucidate important aspects of Standard Model or New Physics. BTeV will have these events archived and will be in position to mine the data.*

We also note that the e^+e^- B factories would have total of 10^9 B anti-B events in an accumulated data sample of 1000 fb^{-1}, should they reach that level; both LHCb and BTeV will surpass them in 2010, but not before. The B factories, however, do not do B_s physics and there is opportunity there for important discoveries with relatively small accumulated luminosities; for example, B_s mixing, should it not be measured at CDF.

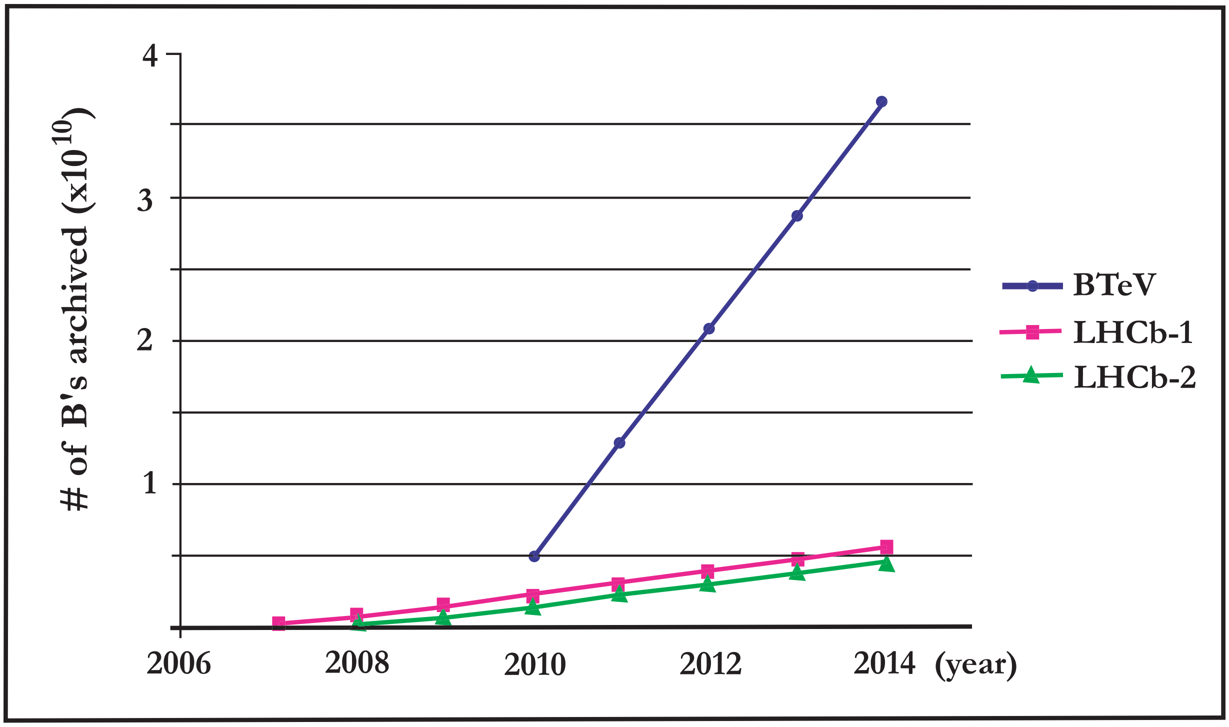


Figure 2: The total accumulated number of b- anti b events at the end of each year for the staged BTeV detector and the two scenarios for LHCb described in the text.

3.5 Specific Comparisons

We now compare BTeV Stage I and II with "LHCb Light" on specific final states. We use four modes of great importance because they give direct determinations of the CP violating angles γ, α and χ, and one rare decay mode.

3.5.1 A Specific Comparison: $B_s \rightarrow D_s^{\pm} K^{\mp}$

A time dependent flavor tagged asymmetry measurement in this mode measures the CP violation angle γ. The branching ratio is estimated as B=3x10^{-4}.

A comparison of the estimated total efficiencies (excluding D_s decay branching ratios), and signal/background (S/B) ratios are given in Table 1. Here $D_s^+ \to K^+K^-\pi^+$ can be reconstructed via either $\phi\pi^+$ or $K^{*o}K^-$. BTeV analyzes them somewhat differently. For $K^{*o}K^-$ BTeV requires both charged kaons to be identified by the RICH detector, while for $\phi\pi^+$ only one charged kaon is required to be identified in the RICH. We have derated the BTeV event numbers by 10% to account for effects due to the 396 ns bunch spacing (see the appendix to the TDR[18]). (The reconstruction efficiency for $\phi\pi^+$ is 2.3%, while for $K^{*o}K^-$ it is 1.3%. (All LHCb numbers are taken directly from the LHCb Light TDR[19] .)

Table 1: BTeV Stage I and LHCb sensitivities for $B_s \to D_s^+K^-$

	BTeV Stage I	BTeV Stage II	LHCb[10]
Yield (2 fb^{-1})	6,750	6,750	7,140
S/B	7	7	>1
$\epsilon \cdot D^2$	9.8%	13%	7.1%
Tagged yield (2 fb^{-1})	660	878	507
Error in γ for 2 fb^{-1}	9.4°	8.4°	14.5°
Error in γ/year (steady state)		10.9°	26.5°

We note that even without the liquid radiator the effective tagging efficiency for BTeV ($\varepsilon \bullet D^2$) is higher than LHCb, this being due to the much lower charged multiplicities in the primary collision.

In Figure 3 we compare the error on γ as a function of time for BTeV and LHCb using the two scenarios for the LHC turn on. We note that at the end of 2010 BTeV will have the best measurement of γ using this method and at the end of 2012 the error will be less than 6°.

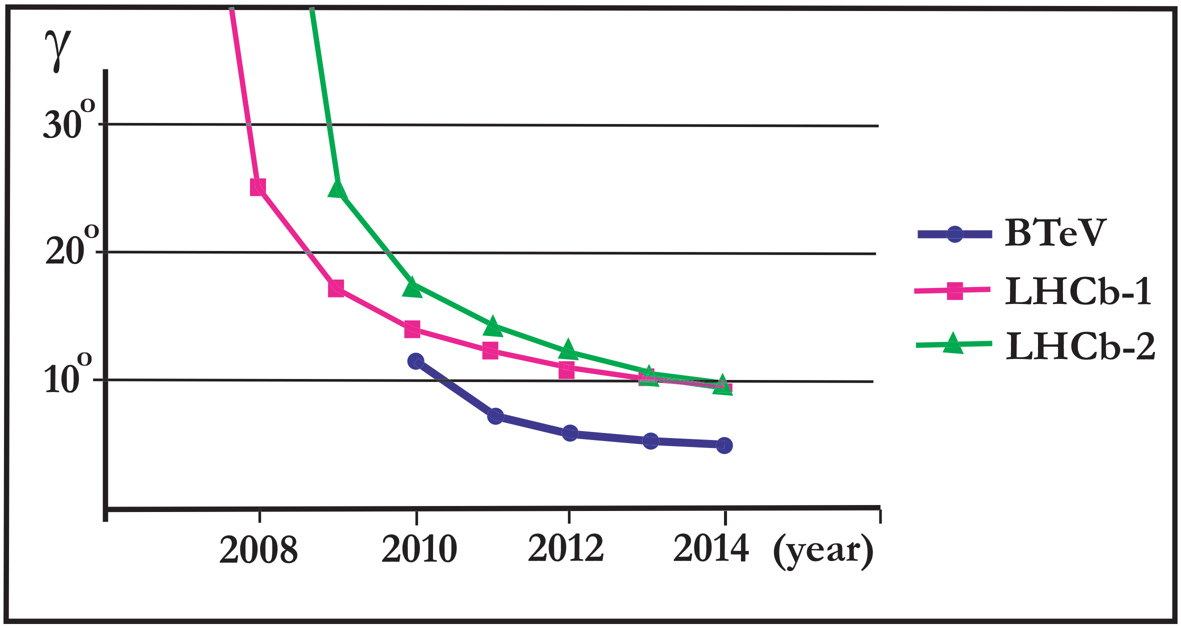


Figure 3: The error in the CP violating angle γ (in degrees) as a function of the end of the year, measured using flavor tagged $B_s \rightarrow D_s K^-$ decays for the staged BTeV detector and the two scenarios for LHCb that are described in the text.

It becomes pertinent to ascertain when the angular uncertainty falls into a range where there really is a meaningful measurement. We turn to current data for guidance. Both Babar and Belle have measurements on the CP asymmetry in the process $B^o \rightarrow \phi K_S$. The measurements of the raw asymmetry proportional to sin2β are 0.47±0.34± 0.07 for Babar and -0.96±0.50±0.10 for Belle[20]. Both of these measurements have ~14° errors and they clearly are not good enough to establish a difference with the value of sin2β from $B^o \rightarrow J/\psi K_S$ decays of 0.74±0.05, which has an error of 2°. This example leads to claim that an error substantially better than 10° on γ will need to obtained before a definitive determination can be made.

Thus LHCb will not likely have a meaningful measurement of γ in either of their turn on scenarios before BTeV, nor will they ever make a measurement as good as BTeV's.

3.5.2 A Specific Comparison: $B^o \rightarrow \rho\pi$

This mode has been extensively analyzed by BTeV[21]. LHCb has analyzed this mode somewhat and listed the results in their new TDR[22]. Their detector is not particular well suited for π^o's. In the $B \rightarrow \pi^+\pi^-\pi^o$ mode they find that 2/3 of the π^o's form two clusters with a mass resolution of 10 MeV, the other 1/3 are merged. In BTeV the π^o mass resolution 3.1 MeV and only about 10% of the π^o's are merged, but can easily be measured with good resolution using the individual crystal energies. The resultant B mass resolutions are 28 MeV for BTeV and 75 MeV for LHCb.

LHCb estimates a signal yield of 7260 events in 2 fb^{-1}(using our values for the branching ratio). However they only quote a limit of <7.1 on the background over signal ratio based on a sample of 5 background events. They do not quote a sensitivity to α. BTeV estimates a sensitivity in α of 6.3^o for the Stage I detector in 2 fb^{-1}, and 4.2^o for Stage II. We can make a estimate of the LHCb sensitivity based on the number of events they will detect and their signal to background ratio, if we assume that their decay time resolution is same as BTeV's and their backgrounds in the Dalitz plot are similar in shape. This exercise yields an error in α for LHCb of 11.7^o in 2 fb^{-1}. *Since LHCb will accumulate only half the integrated luminosity of BTeV per year, it is clear that they will not be able to make a definitive measurement of α, in fact, it is likely that they will not be able to make one at all, not surprising because of the poor energy resolution and segmentation of their calorimeter.* Therefore, it is clear that our results even in Stage I will dominate theirs.

3.5.3 A Specific Comparison: Measurement of χ

The phase of B_d mixing is given by the CP violating angle β. In B_s mixing the phase is called χ and is a fundamental measurement. LHCb because of their relatively poor Electromagnetic Calorimeter must rely on the vector-vector final state in the reaction $B_s \rightarrow J/\psi\ \phi$. Here the sensitivity is related to several questions beyond the event yields and signal to background. The final state particles are in both CP + and CP- final states and the sensitivity is a sharp function of this ratio. The sensitivity also depends on knowing $\Delta\Gamma$, the difference in widths between the two CP states. LHCb claims that with precise knowledge of $\Delta\Gamma$ and a favorable ratio of CP eigenstates, namely that one is dominant, that they will be able to measure χ to about 3.6^o in 2 fb^{-1}. Using the CP eigenstates $B_s \rightarrow J/\psi\ \eta^{(\prime)}$ alone, BTeV's error is 0.7^o and BTeV can add in the $J/\psi\ \phi$ mode if it is at all useful. Since BTeV is expected to accumulate two times as much luminosity per year, we will dominate this measurement even in Stage I. Moreover, BTeV can use its lifetime measurements in $J/\psi\ \eta^{(\prime)}$, a CP + final state combined with the lifetime in the mixed $D_s^+\pi^-$ final state to get a measurement of $\Delta\Gamma$, and thus provide useful information for the analysis of CP violation in the $J/\psi\ \phi$, which can lead to the removal of ambiguities in χ and ambiguities in γ using other final states.

The projection of the sensitivities in χ are summarized in Table 2. The Standard Model expectation for χ is $1\text{-}1.5^o$. Thus measuring χ to better than 1^o, is important, because there are important Standard Model test associated with a precision measurement of χ[23]. New physics, however, can produce significantly larger values, and thus any new measurement could lead to an important result. Although we have listed here the BTeV error using CP eigenstates, BTeV will also measure the $B_s \rightarrow J/\psi\phi$ mode as LHCb does, thus somewhat improving the sensitivity.

Table 2: Comparison of BTeV Stage I and LHCb sensitivities for measuring χ in 2 fb^{-1}, where BTeV uses $B_s \rightarrow J/\psi\, \eta^{(\prime)}$ and LHCb $B_s \rightarrow J/\psi\, \phi$

	BTeV Stage I	BTeV Stage II	LHCb[10]
Yield (2 fb^{-1})	6,800	11,340	100,000
S/B	20	20	>3
$\epsilon \cdot D^2$	9.8%	13%	5.5%
Tagged yield (2 fb^{-1})	660	1474	5500
Error in χ for 2 fb^{-1}	1.1°	0.7°	3.7°
Error in χ/year (steady state)		0.9°	5.9°

CDF and D0 also can use the $B_s \rightarrow J/\psi\phi$ mode to measure χ. Currently both are reconstructing about 1 event per pb^{-1}. This implies that if B_s oscillations are also measured that they each can measure χ to about 13^o [24]. In Figure 4 we compare the error on χ as a function of time for BTeV and LHCb using the two scenarios for the LHC turn on. LHCb will have a chance in 2009 of making a significant measurement of χ, if it is in excess of ~20^o and they collect sufficient integrated luminosity to improve over the combined CDF and DO measurement. At the end of 2010 BTeV will have the best measurement of χ and the error will eventually be less than 0.5^o. *Thus BTeV has the best chance of making a significant measurement if new physics is present and is the only detector that can measure χ if new physics doesn't make a very large contribution.*

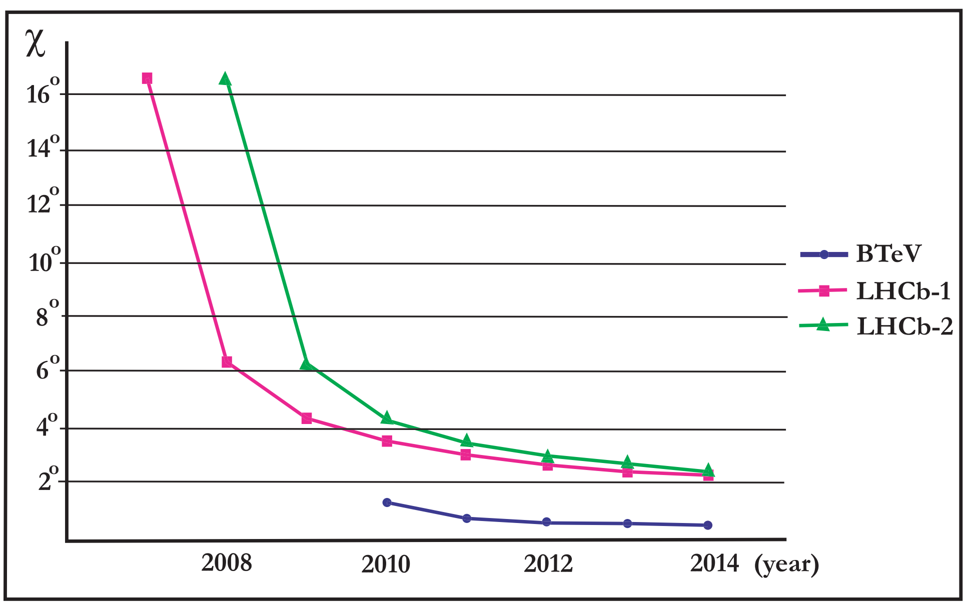


Figure 4: The error in the CP violating angle χ (in degrees) as a function of the end of the year, measured using flavor tagged $B_s \rightarrow J/\psi \ \eta^{(\prime)}$ decays for the staged BTeV detector and the two turn on scenarios for LHCb that are described in the text using the $B_s \rightarrow J/\psi\phi$ decay mode.

3.5.4 Measurement of the Rare Decay $B^o \rightarrow K^{*o}\mu^+\mu^-$

This decay mode is one of the most interesting rare decay modes used for finding new physics by examining the polarizations. Normalizing to a branching ratio of 1.5x10^{-6} the rates for BTeV and LHCb are listed in Table 3. This is one of the best modes for LHCb. They have a special dimuon trigger that enhances their rates in this final state. Here there is no difference between the rates in BTeV Stage I and Stage II. We also list in the Table a "polarization asymmetry quality factor," that is proportional to

$$QF = \sqrt{1000/(\#\,of\ events)} \times \sqrt{(S+B)/S}$$

Table 3: Comparison of BTeV and LHCb sensitivities for $B^o \rightarrow K^{*o}\mu^+\mu^-$

	BTeV	LHCb[10]
Yield (2 fb^{-1})	2277	5546
S/B	7	>0.5
QF	0.71	0.74
Yield in 1 calendar year	1700	1660
QF/year steady state	0.63	1.34

In `Figure 5`, we show the QF versus year. Here LHCb is more competitive than in the other cases. BTeV still dominates at the end of 2010 or 2011.

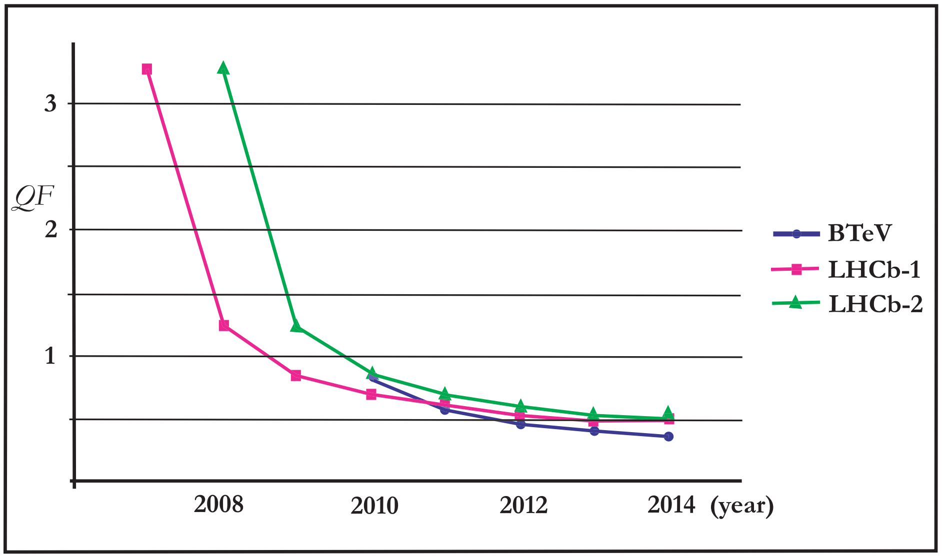


Figure 5: The quality factor QF defined in the text as applied to the decay mode $B^o \to K^{*o}\mu^+\mu^-$, for the staged BTeV detector and the two turn on scenarios for LHCb as a function of the end of year indicated.

3.6 Summary of Comparisons

BTeV has all the proper elements to make it the "best of breed" heavy quark experiment. It has a relatively unbiased vertex trigger that allows it to accumulate b and c quark events at unprecedented rates. Like the B-factories it has both excellent charged particle identification and photon detection. Furthermore it is coupled to a prolific source of b quarks that permits the experiment to collect 1 kHz of b decays. Some examples of BTeV's prowess have been discussed: BTeV will make the best measurements in the world on the important CKM angles α using $B^o \to \rho\ \pi$, γ using $B_s \to D_s^+ K^-$ and χ using $B_s \to J/\psi\ \eta^{(\prime)}$ even with the Stage I detector. Furthermore, BTeV will write to tape a factor of 10 more b events per calendar year than LHCb, allowing for more physics studies. This is of particular importance because there are many new ideas in this field where new decay modes are "discovered" to be of particular value. BTeV will have these on "tape."

The comparisons done here assume two LHC turn on schedules for LHC startup. We have no way of knowing how long it will take for the LHC itself to run at high luminosity and how the interactions with the other detectors, Atlas, CMS and Alice will affect LHCb's ability to have accesses to work on their detector and how many shutdowns the other experiments and the machine will require. BTeV will be the only experiment running at the Tevatron so it will not face these problems.

BTeV is the best detector to discover New Physics or provide crucial information necessary for deciphering any New Physics found at the LHC. LHCb simply cannot do all the necessary physics.

4 DESCRIPTION OF THE IMPROVED SCHEDULING METHODOLOGY

In order to discuss the BTeV schedule, we have to separate the construction of detector and IR components from the installation. The construction spans a four to five year period and involves interactions with many external vendors. The bulk of the installation takes place over a period of ~7 months and largely uses resources under the control of the BTeV project and Fermilab. The assessment of schedules and judgment of adequacy of schedule float depend on this separation.

4.1 Schedule Methodology

The schedule is developed using the computer program OpenPlan, created by the WELCOM Corporation. Subproject managers are responsible for the generation and maintenance of the schedules for their subsystems, in collaboration with the BTeV Project Office.

The schedule is built of tasks of various durations and milestones that are linked to describe the flow and interdependency of the work. The manpower required to complete each task is specified. Separate allocations are made for various types of technical personnel – including mechanical and electrical engineers, designer/drafters and technicians, as well as physicists, both for Fermilab and non-Fermilab employers. Thus, profiles in time of various work groups are readily obtained to aid in the establishment of manpower requirements and the allocation of personnel and to track them as the Project evolves. By entering the average hourly labor cost for each type of manpower, labor cost profiles are extracted for each work group as well as the total labor cost for each subproject and for the entire Project.

The M&S funds needed to complete each task are determined and assigned directly to the tasks in the schedule. Cost plans for each subproject and for the full project are then derived. Using this information, a consistent and viable work plan is established by making appropriate adjustments to the schedule to yield an overall cost plan that matches the profile of funds available from the Laboratory and other sources, and a manpower plan that can be supported by the Laboratory. We note that for all M&S and labor estimates, a detailed Basis of Estimate (BoE) is provided that describes the foundation of and justification for the resources assigned to each task in the schedule. Cost Books have been prepared that provide the source documentation (quotes, invoices, etc.) and supplementary information used in preparing the BoE.

The scheduling program identifies the critical path (or paths) to completion of the Project. This feature calls attention to those tasks that have no ‘float’ or slack and that must therefore be carefully monitored to prevent delay in project completion. Knowledge of the critical path facilitates changes to optimize the work and to hasten completion.

4.2 "Ready by" and "Need by" dates

In order to establish a critical path that separates construction activities and installation activities, we define two groups of dates, as follows:

- "Ready by" dates apply to the construction phase. Each subtask team is asked to make a schedule (taking into account any linkages to other subtasks) for each component that they are providing based on the best knowledge they have or can acquire of activity durations. This leads to a probable date when each component is complete and ready to install – the "Ready by" date. Ready by dates can be given for all components (in which case it is the latest Ready by date of all the subcomponents); of a subgroup of components that are to be installed together; or, where appropriate, of a single component. For example, in the Staged Scenario given above the pixel detector is installed as a single object so the subproject supplies a single "Ready by" date, which is the date they plan to have the detector ready to install in C0. However, the Forward Straw Tracker stations are produced in two sites; become available a station at a time, and are installed a station at a time across the two shutdowns. For them and the Forward Silicon Microstrip Tracker, we specify a "Ready by" date for each of the seven stations.
    - The Ready by date is then tagged in OpenPlan with a "Target Start Date" and a critical path can be calculated relative to this date. This is a classical critical path with no float relative to the Target Start date. OpenPlan also provides lists of tasks with small floats and it is possible to identify "near critical path " activities as well.

- "Need by" dates apply to the installation phase. The leader of the Integration and Installation Subproject, working with the subproject teams, defines an installation schedule relative to the scheduled Tevatron shutdowns. This determines the most probable date on which a detector or a subcomponent is needed for installation – the "Need By" date. As examples, for the Pixel Detector, we establish one "Need by" date since it is installed as a unit. For the Forward Straw tracker we specify a "Need By" date for each station. Some stations are installed in the August 2009 shutdown and some in the July 2010 shutdown.
- The "Installation Complete" date also applies to the installation phase. For each installation activity it is determined by assigning the most probable duration to each part of the installation. The installation complete for each activity also defines a critical path for the installation activity.
- Calculation of "Total Float" and Critical Path: With this approach the "total float" for any given construction activity is the time between its "Need By" date and its "Ready By" date. For an installation activity, it is time between the end of the "Installation Complete" date and the end of the relevant installation period.
    - It is important to note that the construction phase lasts over a calendar period of about 4 – 5 years and should have relatively large floats. The installation phase unfolds in roughly a year and the actual time available for installation is only 30 weeks long for both stages combined. The floats

are generally going to be much shorter by the nature of the installation activity.

- Assessment of the Adequacy of Total Float: whatever the total float turns out to be, it is important to establish that it is adequate to ensure that the task has a very high probability of being completed. We achieve this by examining the critical path and "near critical path" activities, assessing what delays are possible and studying their impact, individually and together, on the schedule. To facilitate this, we have established a set of "Zero Day Contingency" activities positioned at key points of scheduling uncertainty. We then add our estimate of possible schedule contingency usage for each activity, which generates an alternative schedule with a distributed float, rather than one concentrated at the end. These delays could change the project critical path. If after distributing this "delay", the project still concludes before the "Needed By" date, then we conclude that the subtask is highly likely to be completed on schedule. This assumes that the delays all occur.

5 DESCRIPTION OF THE STAGED INSTALLATION

5.1 Introduction

The installation plan is now quite robust for the following reasons. First, the length of time for the most complicated portion of the installation has been increased from 16 months to 30 months for activities in the collision hall and even more for activities in the counting rooms. Second the previous plan highlighted procedures and activities that were not optimum and adjustments to those items have been made to reduce the installation time required. Finally the detector sub-projects have improved the quality of the estimates for the installation tasks. The requirement that each system undergo extensive testing prior to moving into the Collision Hall is retained and is the key to reducing the check out time after the sub-detectors are installed.

The installation activities for each of the shutdowns are described in the following sections. The charts illustrate the work flow in each shutdown with the shutdown divided into one week periods for planning purposes. Many of the tasks can actually be accomplished in less than a week.

5.2 Installation Activities in the C0 Assembly Hall and C0 Collision Hall Before 2009

The C0 assembly hall is used for the assembly of five large objects for the BTeV detector and for the staging of smaller detector elements. Each large object needs to occupy the assembly hall for approximately 4 to 6 months. The assembly hall can hold two large objects that are being worked on. For example, the first three objects are the vertex magnet and the two toroids. Before the construction of the second toroid can begin the vertex magnet or other toroid must be moved into the collision hall.

Figure 6 illustrates the use of the assembly hall during the 5+ year construction period.

Access to the assembly hall will be limited during phase I of the C0 building outfitting. In addition to installing the infrastructure for testing the magnets, access to the assembly hall will be needed for installing the elevator and constructing the block wall that will close off the counting rooms from the assembly hall high bay. The only other access to the assembly hall that is required is in phase II of the building outfitting when the HVAC equipment is moved to the mechanical room located under the loading area. This operation only requires a few days access to the east end of the assembly hall.

Assembly of the South Toroid and Vertex magnet can proceed after beneficial occupancy of the assembly hall from C0 outfitting phase I is accomplished. Assembly of both magnets will require a few months and magnetic field mapping will require an additional few weeks. The assembly of the North toroid will be very similar to the South toroid. However, the North toroid will have a 4" thick steel filter plate extending on the north side. It is expected that the North toroid will be in the assembly hall at the same time as the construction of the tank for the RICH detector. The assembly of both requires a significant amount of welding and will be a somewhat dirty operation. There are advantages to performing this assembly work in the same time frame but it is not essential. Additional work on the RICH will include mounting mirrors, windows and, at least, the top PMT array.

After the North toroid is installed, the support structure for the EMCAL will be moved to the assembly hall. Crystal and PMT assemblies will be loaded in the structure as they are available. The RICH structure will be moved in to the collision hall to provide room for staging of the final detector elements but the EMCAL will remain until the start of the first extended shutdown in 2009

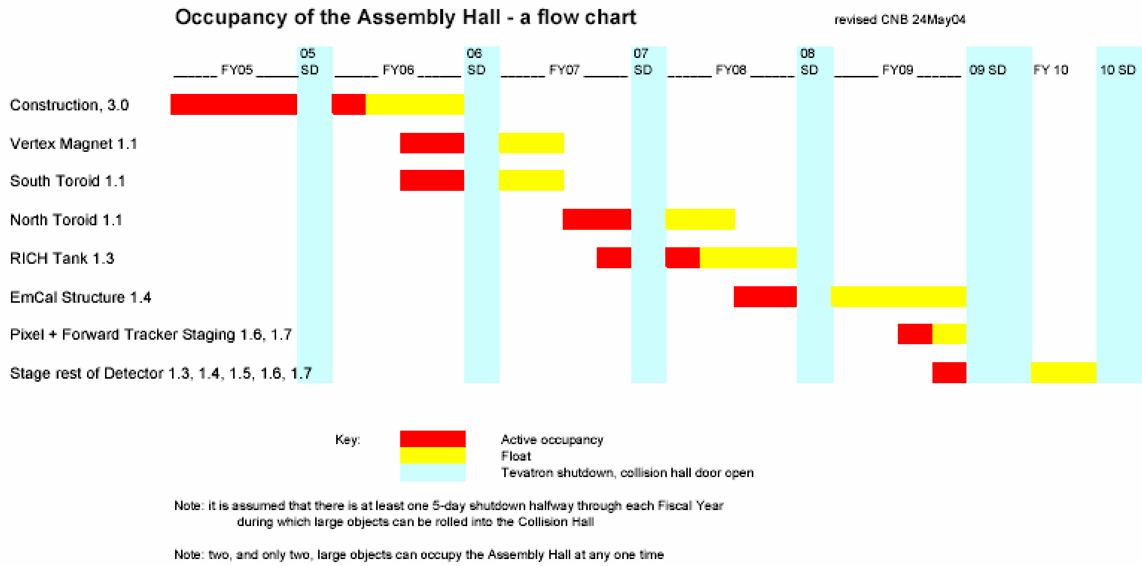


Figure 6: Orchestration of Activities in the C0 Assembly Area

5.2.1 2005 Shutdown

One purpose of the first shutdown is to remove the existing magnets from the collision hall and reconfigure C0 to a normal straight section. In addition LCW lines are extended from the Tevatron tunnel to the collision and assembly halls. Barrier walls will be installed at the collision hall/Tevatron tunnel interface to eliminate any oxygen deficiency hazard (ODH) in the collision hall from a cryogen venting in the Tevatron tunnel. Vacuum gate valves will be installed just outside the collision hall to allow isolation of the vacuum of the beam pipe in the collision hall from the Tevatron vacuum. A temporary beam pipe will be installed in the collision hall with pump out ports and flange connections to allow removal of sections as detector components are installed. All of the activities are beneficial to the overall schedule but only one task is required. The essential task of this shutdown is the installation of the LCW headers that extend to the assembly hall. These are required for testing of the vertex magnet and toroids. Several work around options are available to accomplish the magnet removal tasks if this work is delayed until a following shutdown.

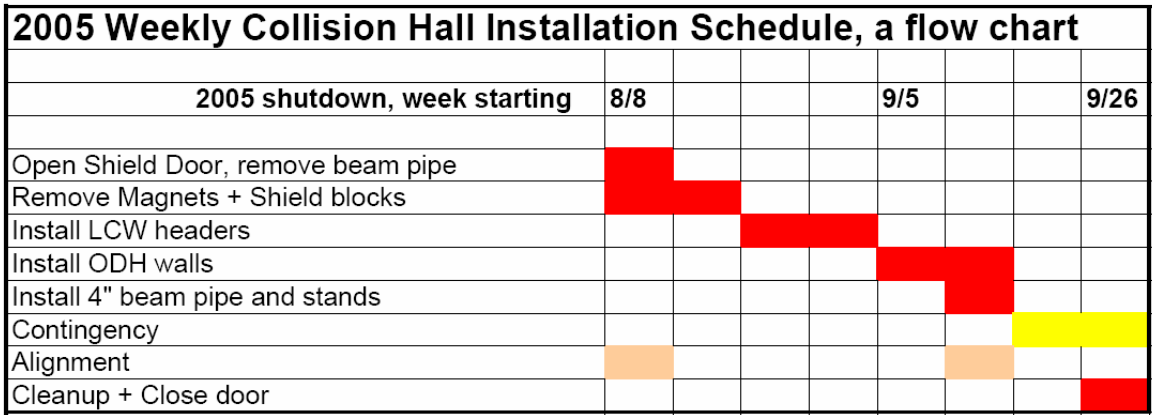


Figure 7: Flow chart of activities in the C0 Collision Hall in the 2005 shutdown

5.2.2 2006 Shutdown

One purpose of the second shutdown is the installation of the power/power panels and smoke detection equipment. These tasks are part of the C0 outfitting phase I. In addition the vertex magnet and South toroid could be installed. Infrastructure such as water cooled buss and electronics cooling water manifolds could also be installed. It will require one day to move either magnet to its approximate position. Final adjustment will require additional time. After either magnet is in place, work can proceed with connecting power, LCW, control and monitoring. These activities can proceed in parallel or in series and will require a few days per magnet for a two man crew.

Complete installation of the vertex magnet and B2 compensating dipoles will allow beam studies of these two elements of the final detector. However the essential function of this installation phase is to clear the assembly hall to provide space for the assembly of following detector components. Even if the installations are not complete the essential function will have been accomplished when one or both magnets are moved from the assembly hall. In fact the magnets do not even need to be installed on the beam line. Both can fit in the collision hall between the beam pipe and the East wall. Thus either or both could be moved into the Collision Hall in a very short shutdown without venting the beam pipe vacuum. Tevatron operation records demonstrate that there is a high probability of at least one 5-day shutdown halfway through each Fiscal Year

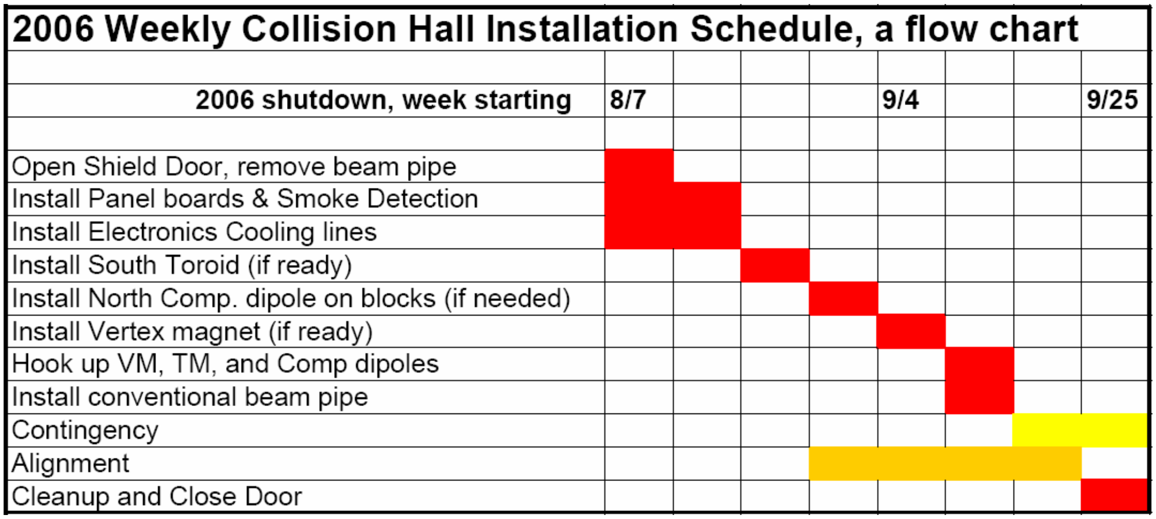


Figure 8: Flow chart of activities in the C0 Collision Hall in the 2006 shutdown

5.2.3 2007 Shutdown

The final C0 outfitting equipment installed in the collision hall are the fan coil units that supplement the central HVAC. The HVAC equipment installed in the mechanical room also needs to be commissioned and final adjustments may need to be made to the ductwork in the collision hall. This work could be accomplished during the same shutdown as the installation of the North toroid. However, if the installation of the North toroid is delayed it can be rolled in to the collision hall in a short shutdown later in the year. As with the previous magnet installation, the essential function is to clear the assembly hall to provide space for the assembly of following detector components.

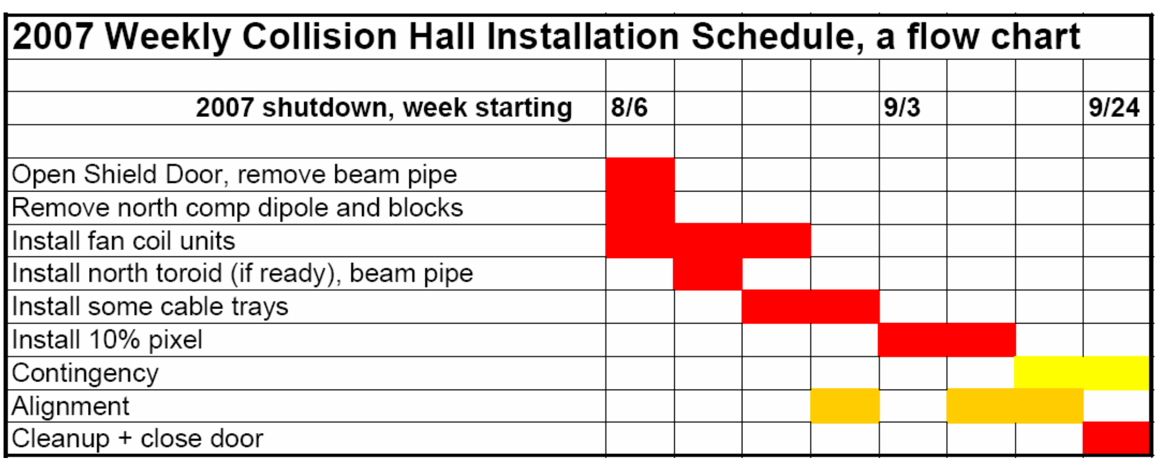


Figure 9: Flow chart of activities in the C0 Collision Hall in the 2007 shutdown

5.2.4 2008 Shutdown

The two main activities in this shutdown are the installation of the RICH tank and the installation of most of the infrastructure such as cooling manifold,gas lines, cable trays and some cables. Some racks on the west side of the will also be installed. The RICH tank with top PMT array weighs approximately 10 tons. It would be rolled in to place with small Hilman or similar rollers.

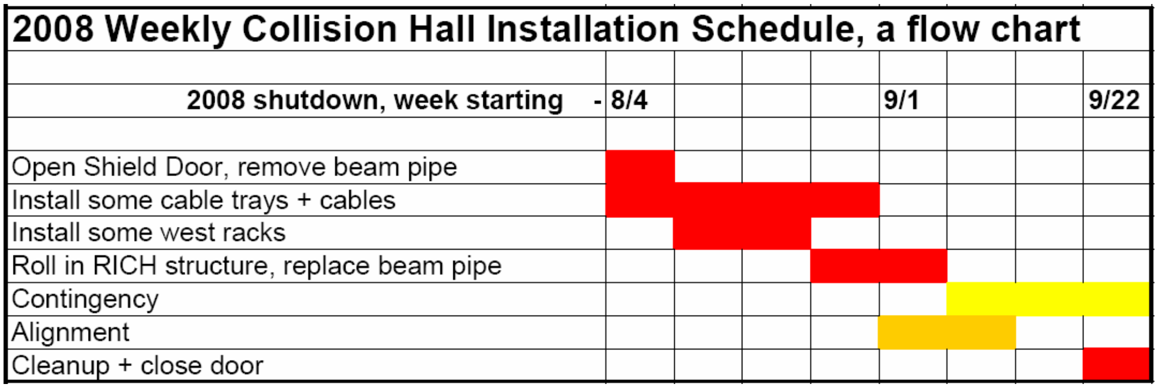


Figure 10: Flow chart of activities in the C0 Collision Hall in the 2008 shutdown

5.3 Installation activities in the C0 Collision Hall in 2009 and 2010

The flow charts below illustrate the flow of activities in the two extended shutdowns. The activities shown is these charts were scheduled to occur in a single 16 week shutdown in the original installation plan. In the staged installation plan these activities are now distributed over 2 extended shutdowns of 30 week combined duration. The major focus of the 2009 shutdown is the installation of the pixel detector and forward tracking. The installation of the pixel detector and forward tracking stations is complete 6 weeks before the end of the first extended shutdown. The focus of the 2010 shutdown is the installation and connection of the remaining crystals in the EMCAL. Based on single shift installation this activity is complete 2 weeks before the end of the final shutdown. The installation of the individual components of the various sub-detectors is shown in the flow chart are discussed in greater detail in section 7.

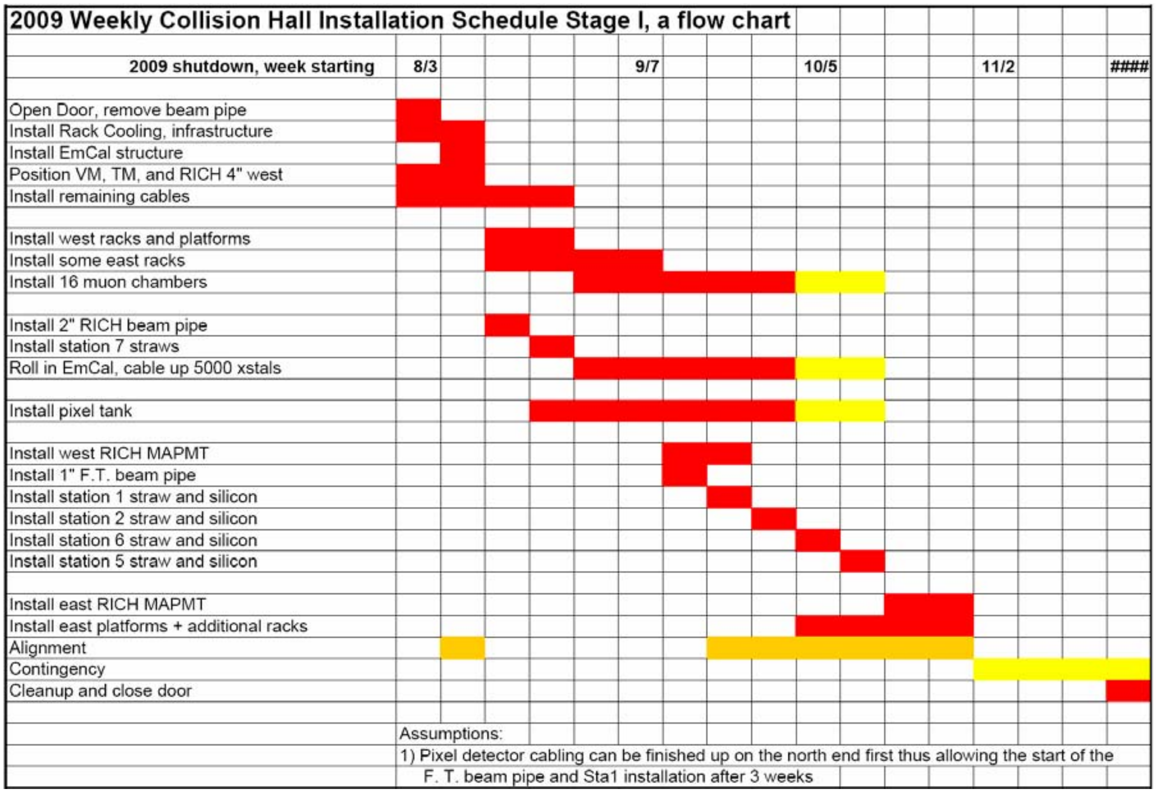


Figure 11: Flow chart of activities for installation of the Stage 1 detector the C0 Collision Hall in the 2009 shutdown

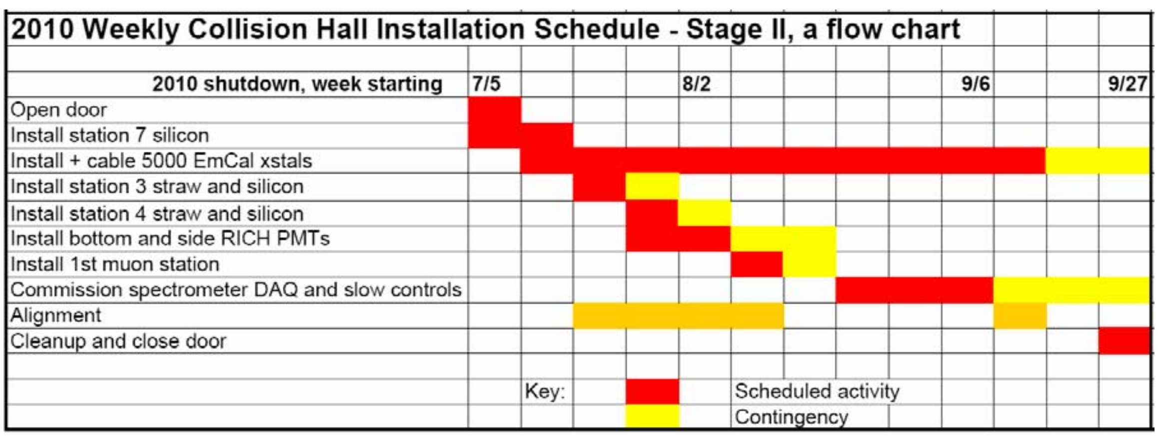


Figure 12: Flow chart of activities for installation of the Stage 2 detector the C0 Collision Hall in the 2010 shutdown

5.4 Installation Activities in the C0 Counting Room

The C0 building outfitting phase II that finishes the counting rooms must be completed by mid CY 2008. At this point the computer room floors are finished and power is distributed to breaker panels. The final configuration for racks must be finalized at this time.

Installation of racks for the 1st floor counting room can begin. These racks require power, water cooling and rack protection monitoring connections. The work for distributing and connecting these services to the rack can begin.

All but a few racks in the 3rd floor counting room are for the L2/3 trigger. These are high density computing racks and it is expected that they will be cooled by air-chiller units that circulate air through the floors to vents in front of the racks to form a warm aisle-cold aisle circulation pattern. The equipment for this cooling arrangement is installed as part the phase II outfitting. However, power will need to be distributed to the individual racks.

The High Voltage power supply racks will be located in the 1st level electronics bridge. The racks will be installed and power distributed to them. These racks are air cooled with heat dissipated to conventional HVAC.

The slow controls racks will be installed in the 2nd level electronics bridge. The racks will be installed and power distributed to them. These racks are air cooled with heat dissipated to conventional HVAC.

Installation will be scheduled for efficiency while meeting the installation schedules of the trigger and DAQ subprojects. The staged installation schedule provides a period of over one year from when the first item is required until the last item is required. There are no access restrictions to the counting rooms during this installation period

6 SUMMARY OF REVISED COST AND SCHEDULE FOR THE BTeV PROJECT

This section presents the project-wide summary of the new cost and schedule.

6.1 Key “Ready by” and “Need by” Dates for the BTeV Project

The improved scheduling methodology described above has been applied to each Level 2 subtask of BTeV. The floats for most of the projects have been increased significantly. In some cases, this has been due to reallocation of resources between projects by the BTeV Project management and in other cases by reallocation within subprojects by the Level 2 manager. New resources from INFN have allowed restructuring of the funding profile in significant ways. Choke points have been located and actions have been taken to remove them. Hidden contingencies have been made explicit.

The result of this effort is that all subprojects and the full BTeV Project now have floats of greater than 145 working days. There are about 20 working days per month. Schedule floats for key activities are shown in Table 4.

Table 4: Construction "Need by", "Ready by" dates and Floats by subtask. In the staged column, we indicate NA if the device is installed before the 2009 shutdown, No if not staged, Yes if staged. The number in parentheses indicates whether it is needed for the run starting in 2009 (staged detector 1) or 2010 (the full, stage 2 detector).

Subtask	"Ready by"	"Needed by"	Float (working days)	Staged
Magnet, Toroid (1.1)	Jul. '06	Feb. '07	145	NA
Pixel Detector (1.2)	Sep. '08	Aug. '09	229	No(1)
RICH Vessel (1.3)	Oct. '07	Sep. '08	202	NA
RICH MaPMT	Jun. '08	Nov. '09	235	Yes(1)
RICH Liquid Circulation System	Jul. '09	May '10	197	Yes (2)
50% Crystals Loaded	Apr. '08	Sep. '09	229	Yes(1)
100% Crystals delivered	Sep.'09	Aug. '10	191	Yes(2)
Muon Station 2/3 (1.5)	Sep. '07	Aug. '09	474	Yes(1)
Muon Station 1	Sep. '08	Aug. '10	475	Yes(2)
Muon Gas System	Mar. '07	Sep. '08	382	Yes(1)
Straw Station 1,2,5,6,7 (1.6)	Oct. '08	Aug. '09	218	Yes(1)
Straw Station 3,4	May '08	Jul. '10	>540	Yes(2)
Microstrip Tracker (1.7)	Dec. '08	Aug. '09	186	Yes(1,2)
50% of Trigger (1.8)	Feb '09	Oct. '09	156	Yes(1)
100% of Trigger	Sep. '09	Aug. '10	223	Yes(2)
50% of Data Acquisition (1.9)	Sep. '08	Aug. '09	220	Yes(1)
100% of Data Acquisition	Mar. '09	Jul. '10	310	Yes(2)
C0 IR Quads(2.0)	Dec. '08	Sep. '09	200	No(1)
C0 IR Spools	Jan. '09	Sep. '09	175	No(1)
C0 Assembly Area (3.0)	Dec. '05	Jul. '06	157	NA

To assess whether these floats are adequate to ensure completion of the project on schedule, we make assessments of what delays could occur and distribute them throughout the schedule. If, after redoing the time analysis, float remains, then we can be confident that the schedule will be met.

We have examined the schedule of the subtasks and the overall schedule, as well as the risks associated with each subtask, and believe that the key areas of concern in this schedule are:

- The IR spools and quadrupoles
- The Pixel Detector
- The first 50% of the Trigger system
- Stage 2 of the EMCAL crystals (delivery, installation)

The shortest float for these activities is 156 working days (& calendar months) for the first 50% of the Trigger System. While there are activities with shorter floats that will bear watching, these are the ones that appear to have the most risk of schedule slip due to issues that are examined in section 7.

The BTeV Construction projects proceed in parallel without very much interference. Detailed analysis of the schedules in Open Plan are performed on each subproject and may be seen represented at a high level (that is, much of the fine detail is suppressed) in Section 7 below by what we call "project flow diagrams." In Figure 13, we show Gantt charts of the critical paths for three of the four subprojects that have the short floats and constitute our critical and near-critical path for the full BTeV Project.

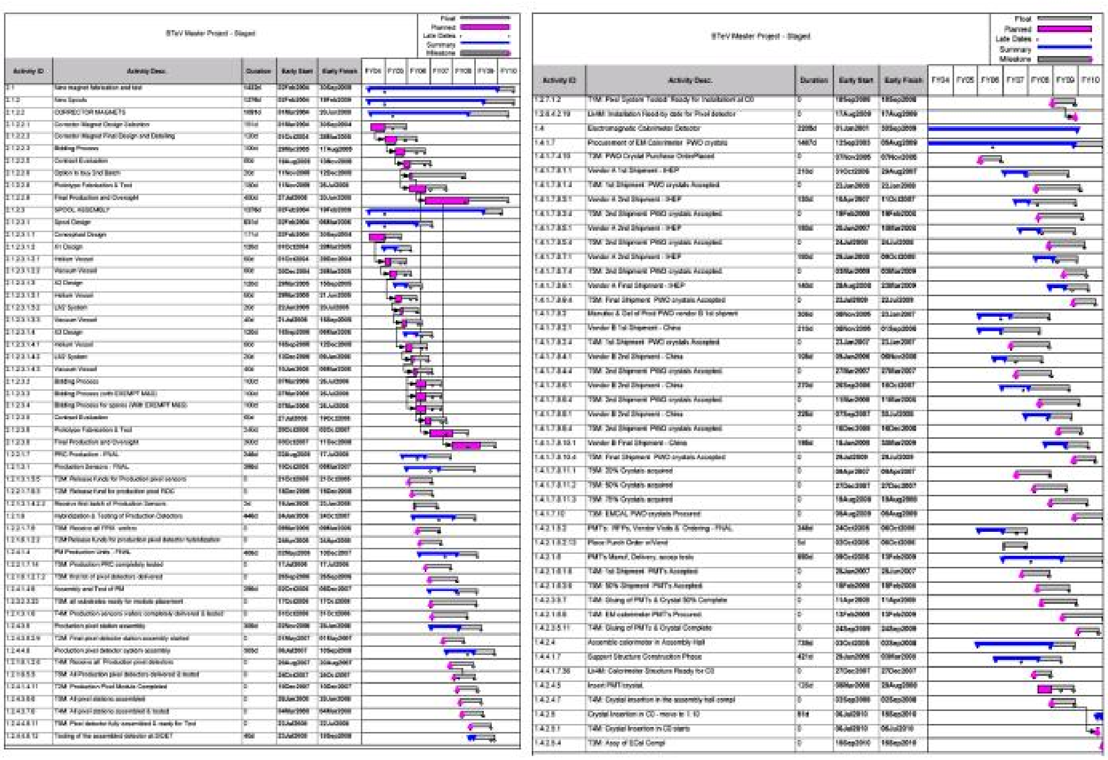


Figure 13: Gantt Chart of the Critical Paths for the C0 IR (WBS 2.0), the Pixel Detector (WBS 1.2) and the Electromagnetic Calorimeter (EMCAL, WBS 1.4)

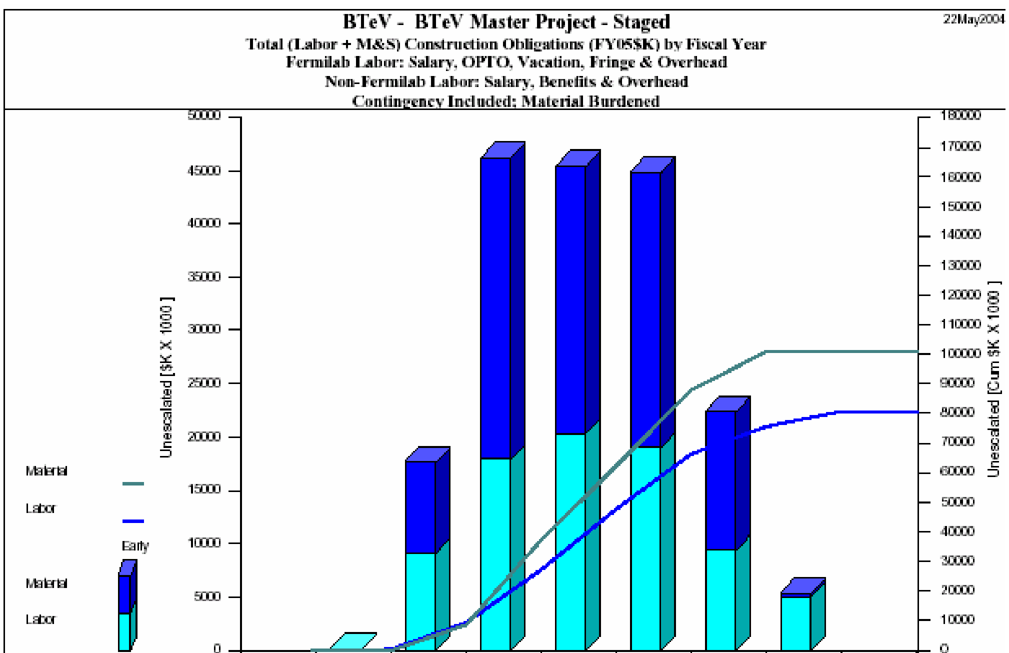
6.2 New Budget Profile for BTeV Project

The budget profile, by subtask, is given in Table 5 for the “staged scenario” considered here. This is in FY’05 dollars. The data are plotted in Figure 14.

Activity ID	Base Cost ($)	Material Contin-gency (%)	Labor Contin-gency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.1	1,866,664	26	24	178,045	1,438,283	465,137	256,776	6,868	0	2,345,109
1.2	15,363,375	43	39	2,283,124	7,816,045	6,132,910	4,910,051	507,844	0	21,649,974
1.3	12,095,831	38	28	672,598	4,551,404	6,520,698	3,888,084	853,837	0	16,486,621
1.4	12,553,126	35	28	539,890	2,490,006	4,797,627	4,714,283	4,223,956	0	16,765,762
1.5	4,211,242	45	27	520,654	2,412,260	1,851,111	1,097,154	0	0	5,881,179
1.6	9,759,474	26	32	817,027	4,041,326	4,213,614	3,255,255	229,146	0	12,556,368
1.7	7,473,389	36	32	953,351	2,290,898	2,543,365	4,001,984	220,456	0	10,010,054
1.8	12,144,431	33	53	783,388	2,570,916	2,229,985	6,618,435	4,972,216	0	17,174,940
1.9	12,184,272	41	29	436,497	2,662,466	3,624,290	5,955,402	3,598,323	109,104	16,386,082
1.10	7,592,576	22	78	191,057	843,782	1,619,752	2,801,158	3,250,384	3,684,585	12,390,718
2.0	26,026,672	36	40	7,455,048	10,966,126	7,250,517	6,096,068	3,186,572	956,473	35,910,804
3.0	5,771,006	21	20	1,763,228	2,592,526	2,605,706	0	0	0	6,961,460
4.0	5,713,380	22	23	1,089,928	1,425,459	1,433,768	1,301,795	1,302,084	493,472	7,046,506
Total	132,755,438	35	39	17,683,835	46,101,497	45,288,480	44,896,445	22,351,686	5,243,634	181,565,577

Table 5: Cost profile by subtask and fiscal year for BTeV Project with staged scenario (no IR spares)

The total cost is compared with that of the CD-1 review in Figure 15. The cost has risen by $4.15M (FY’05$) because we have added $2.11M contingency to the Installation and Integration subtask (WBS 1.11) based on advice from the CD-1 review; there is an increase of $0.58M to continue the Project Office for a longer time; and there are several other adjustments that are discussed in section 7.



		FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11
Labor	Early	0	0	9075	17835	20260	19007	9370	4968	0
Material	Early	0	0	8522	28235	25001	25841	12948	268	0
Labor [Cum]	Early	0	0	9075	26910	47170	66177	75547	80535	80535
Material [Cum]	Early	0	0	8522	36758	61759	87600	100548	100816	100816

Figure 14: Cost Profile for BTeV Project with Staged Scenario

Total Cost in FY05$				
In $millions		Apr Rvw	May Rvw	Difference
1		$ 127.71	$ 131.68	$ 3.97
1.1		$ 2.22	$ 2.35	$ 0.13
1.2		$ 21.65	$ 21.65	$ -
1.3		$ 16.44	$ 16.49	$ 0.05
1.4		$ 16.32	$ 16.77	$ 0.45
1.5		$ 5.14	$ 5.89	$ 0.75
1.6		$ 12.27	$ 12.57	$ 0.30
1.7		$ 10.00	$ 10.01	$ 0.01
1.8		$ 17.05	$ 17.17	$ 0.12
1.9		$ 16.34	$ 16.39	$ 0.05
1.10		$ 10.28	$ 12.39	$ 2.11
2		$ 36.06	$ 35.91	$ (0.15)
3		$ 7.21	$ 6.96	$ (0.25)
4		$ 6.48	$ 7.06	$ 0.58
		$ 177.46	$ 181.61	$ 4.15

Figure 15: Comparison of costs in staged scenario with cost for schedule given in CD-1 review

6.2.1 M&S Profile

The M&S Profile is shown in Figure 16. Compared to the M&S Profile shown at the CD-1 review, it shows more funding in FY'06 and less in FY'09. There is a small amount now in FY'10, due to the staging.

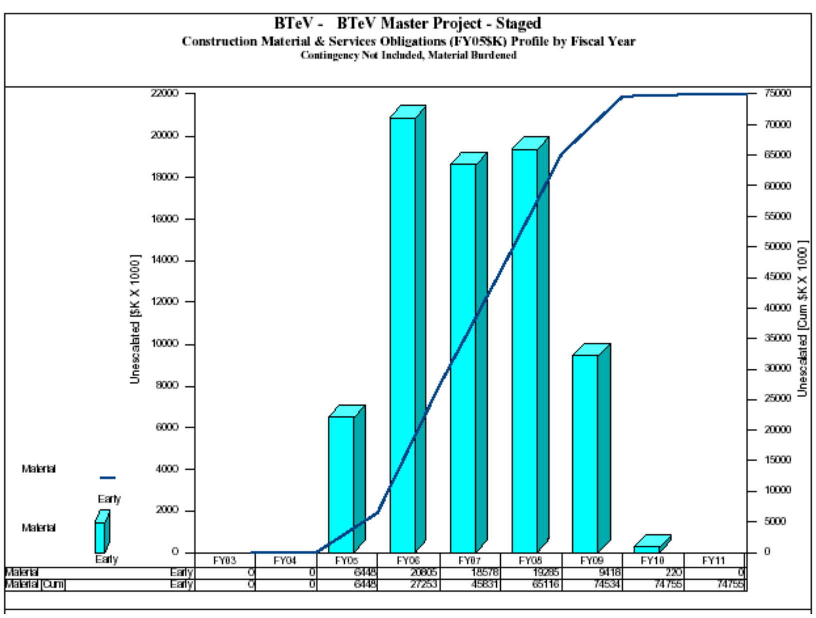
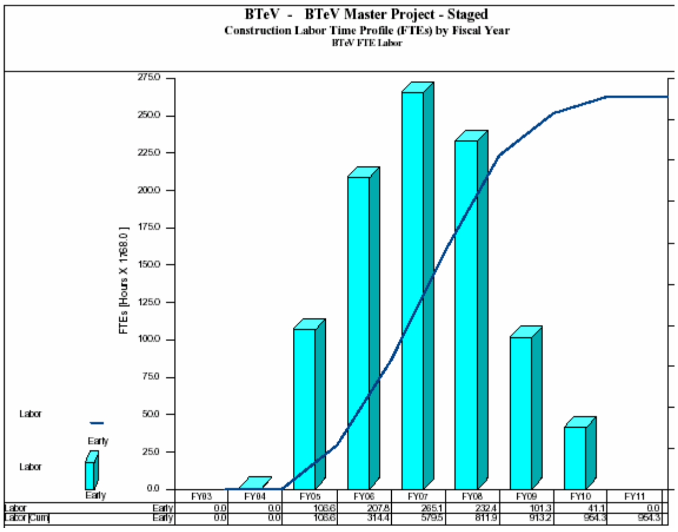


Figure 16: M&S Profile (without contingency) in FY'05 dollars for the staged scenario

6.2.2 Labor Profile

The labor profile for this scenario is shown in Figure 17. It is similar to that shown in the CD-1 review except that it extends into 2010, is lower in 2009, and is a bit shifted towards earlier years. The total effort is only higher by a few FTE-years.



6.2.3 Comparison of Budget Profile to Availability of Funds

Figure 18 and Table 6 show the BTeV cost profile from Open Plan and compares it the availability of funds of all types, including funds from INFN that have been approved, contingent of course on the project going ahead in the US, and forward funding arrangements from Syracuse University. Other forward funding arrangements and possible funding from the US NSF and foreign sources are not yet secure and are not taken into account. There are adequate funds, including contingency, to execute the plan presented here.

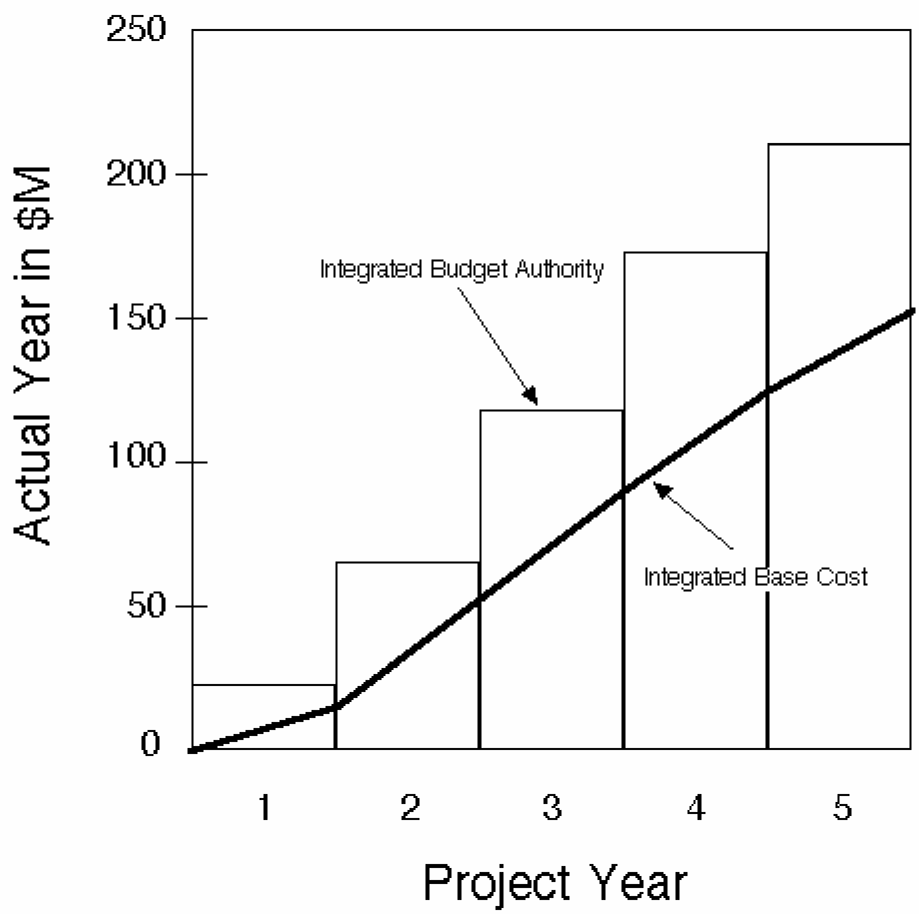


Figure 18: Plot showing the availability of funds (histogram) vs the cost profile from the resource loaded cost and schedule in Actual Year dollars for the BTeV Project, R&D, and Operations (IR spares)

Cost Profile - M$ AY	FY05	FY06	FY07	FY08	FY09/10	
Equipment Base Estimate	6.75	31.3	37.9	35.2	19.3	130.45
Contingency	2.2	10.5	13.5	12.9	8.1	47.2
Total Equipment	8.95	44.9	48.2	49.3	31.5	182.85
IR Spares	1.5	0	1.7	1.8	1.7	6.7
IR Spares Contingency	0.6	0	0.5	0.7	0.7	2.5
R&D	6.75	2.2	0	0	0	8.95
R&D Contingency	2.1	0.6	0	0	0	2.7
Total BTeV Costs	19.9	47.7	50.4	51.8	33.9	203.70
Availability of Funds - M$ AY						
R&D DOE	4.24	2.2	0	0	0	6.44
OP DOE	2.1	0	2.2	2.3	2.4	9
MIE DOE	6.75	39	49	49.4	42.5	186.65
Total DOE	13.09	41.2	51.2	51.7	44.9	202.09
Univ Forward Funding	7.5	0	0	0	-7.5	0
INFN	0.75	1.73	1.88	3	0.15	7.51
NSF	0	0	0	0	0	0
Total Anticiapted BA	21.34	42.93	53.08	54.7	37.55	209.6
Integrated Total BTeV Base Cos	15	51.6	88	126.2	151.3	
Integrated Total BTeV BA	21.34	64.27	117.35	172.05	209.6	

Table 6: Cost Profile vs Budget Authority in Actual Year dollars vs Fiscal Year. Included are construction (equipment), R&D, operations (IR spares) and contingency

7 SUBPROJECT SCHEDULE NARRATIVES

In this section, each subproject presents a narrative of their revised cost and schedule.

7.1 Schedule for Vertex Magnet, Toroid Magnets and Beampipes (WBS 1.1)

7.1.1 Introduction

7.1.1.1 Description

Four large extended mechanical assemblies dominate the layout of the BTeV spectrometer: the Vertex Magnet (dipole), the muon toroids, and the Tevatron beam pipe. The active detector elements of the spectrometer must be designed to fit within the constraints presented by these components.

The Vertex Magnet in the BTeV spectrometer provides the magnetic field around the Tevatron collision point that enables the silicon pixel detector to determine both the direction and momentum of particles produced in the proton-antiproton collisions. This is essential for the proposed displaced vertex trigger to work. The forward tracker uses the full field volume from the particle interaction to the end of the magnet, including the field beyond the pixel detector, to produce an even better measurement of the momentum than is possible with just the pixel detector alone.

The Vertex Magnet is based on the existing SM3 magnet (currently part of the decommissioned Fermilab MEast Spectrometer). The magnet operated in MEast from 1982 until 1997, at a central field of about 0.8 Tesla, serving experiments E605, E772, E789, and E866. The vertical deflection of the Tevatron beam by the Vertex Magnet is compensated by two conventional dipoles at each end of the Collision Hall.

The two muon toroids at the north end of the Collision Hall provide the bend field that enables the muon chambers to detect and determine the momentum of energetic muons from the collision point. The toroids at both the north and south end of the Collision Hall provide support for the compensating dipoles. Both the north and south pair of toroids also provide the absorber material that prevents hadrons, electrons and photons from penetrating and registering in the muon detectors. To provide both a large integrated magnetic field, and enough absorption of hadrons, each toroid is constructed of a meter thick soft iron core energized by a pair of coils that span both toroids in the pair. The iron slabs that form the toroids will be recovered from the existing SM12 magnet in the MEast Spectrometer.

The beam pipe provides the vacuum for, and encloses, the circulating Tevatron proton and antiproton beams. It must be able to conduct the wall current associated with the circulating beams. It must also be as thin as possible in order to minimize the reinteraction of particles emanating from the collision point. The plan is to construct the beam pipe in sections. The 1" diameter beam pipe in the region of the forward tracking chambers will be made by modifying the existing CDF RunIIb beryllium beam pipe.
The 2" diameter beam pipe inside the RICH detector will be constructed by modifying the existing CDF Run I beryllium beam pipe. Since the Vertex Magnet and muon toroids are very large assemblies, they will be assembled in the C0 assembly building and rolled into the C0 Collision Hall.

7.1.1.2 Staging

These components are necessary to any data-taking in BTeV and must be available for the first part of the run with the "stage 1" detector. Therefore, in the revised version of the Open Plan WBS1.1 schedule, there are no items that have been delayed until FY2010. However, the 'needed by' date has been adjusted for the components in this subproject to match the currently planned schedule for the Assembly Hall. These somewhat later 'needed by' dates have resulted in substantially increased float in the WBS1.1 Open Plan schedule.

7.1.2 Project Flow and Cost

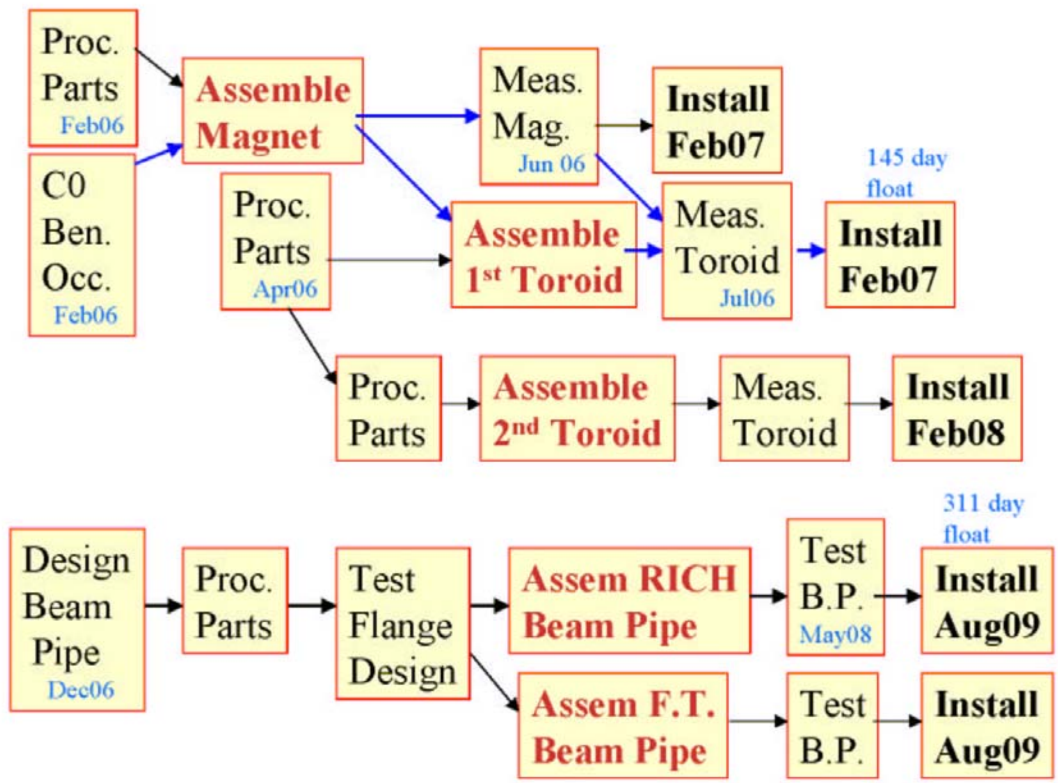


Figure 19: Project Flow for WBS1.1.

7.1.2.1 "Ready by" and "Need by" dates

Device	"Ready by" Date	"Need by" Date	Total Float
Vertex Magnet	Jun. '06	Feb. '07	
North Toroid	Jul. '06	Feb. '07	145
South Toroid		Feb. '08	
RICH Beam Pipe	May '08	Aug. '09	311
Forward Tracker Beam Pipe	May '08	Aug. '09	

Table 7: "Ready by" and "Need by" dates for WBS 1.1

Although this subproject has the smallest total float, 145 days, of any project reported in BTeV, 145 days is a very large percentage of the total time required to execute the project, the subproject has very little risk since each part of it has been done successfully before, and since the "needed by" date is still 18 months ahead of running so there is ample time to develop workarounds if an unforeseen problem should emerge.

7.1.2.2 Project Flow

A block diagram of the Project flow is shown in Figure 19: Project Flow for WBS1.1. The procurement of iron and the preparation of the iron blocks for the magnets and toroids takes place in the Meson Detector Building at Fermilab. The major expenses associated with the disassembly of the SM3 and SM12 magnets are not started until FY06 for funding reasons. This still leaves a large float of 145 days for the magnet reconstruction, a fairly conventional project that is similar to other magnet construction projects done at Fermilab.

7.1.2.3 Labor Profile

Figure 20 gives the labor profile (in FTE's) vs Fiscal Year for this subproject.

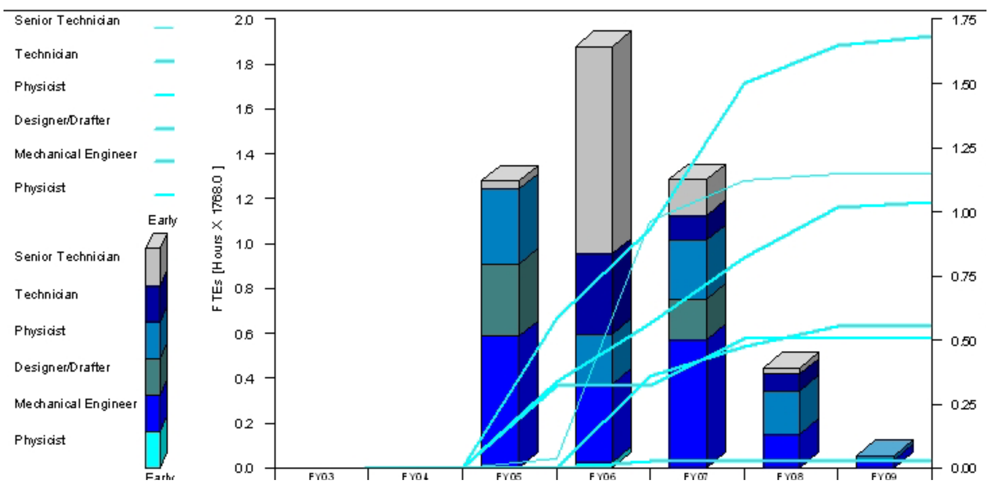


Figure 20: Labor Profile (FTE) vs FY

7.1.2.4 Cost Profile

Figure 21 and Table 8 give the cost profiles for this project. The Figure 21 values are without contingency, which however is shown in Table 8.

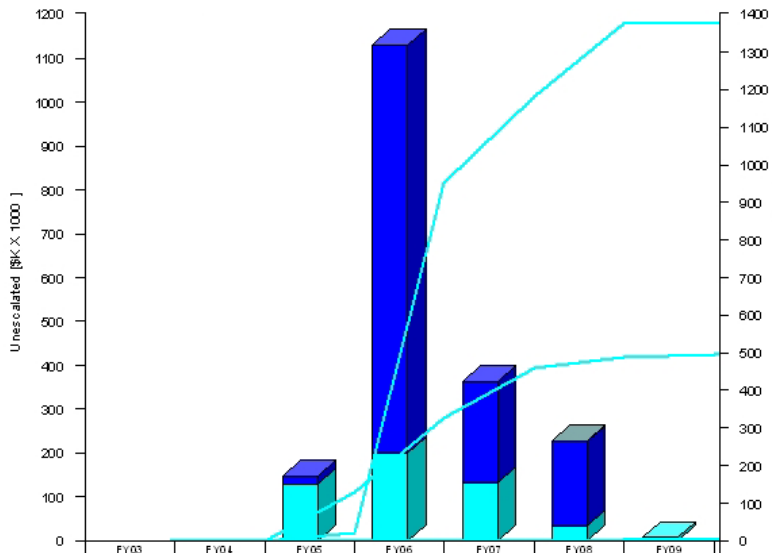


Figure 21: Cost (without contingency) vs FY

7.1.2.5 Critical Path

The critical path combines the Vertex Magnet and Toroid assembly projects since they will both be assembled using the same 30-ton crane in the C0 Assembly Building. The Vertex Magnet will be assembled first followed by the south toroid assembly. The assembly of the north toroid will occur after either the Vertex Magnet or the south toroid has been rolled into the C0 Collision Hall.

The procurement of the beam pipe parts is delayed until FY07 for funding reasons. Nevertheless, the resulting float of 311 days is comfortably large for a beryllium beam pipe project that is similar to recent beam pipe projects for CDF and D0.

7.1.2.6 OBrowser view of costs

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.1.1	Vertex Magnet	587,042	26	24	101,871	634,930	0	0	0	736,801
1.1.2	Muon Toroids	873,818	29	23	57,019	781,046	280,786	0	0	1,118,852
1.1.3	Beam Pipes	338,646	16	26	0	2,846	165,119	237,544	0	405,509
1.1.4	Magnet & Beampipe Software	0	0	0	0	0	0	0	0	0
1.1.5	Integration & Testing	0	0	0	0	0	0	0	0	0
1.1.6	Vertex/Toroidal Mags and BeamPipe Subproj Man	67,158	25	25	19,155	19,460	19,231	19,231	6,868	83,947
1.1	**Subproject 1.1**	**1,866,664**	**26**	**24**	**178,045**	**1,438,283**	**465,137**	**256,776**	**6,868**	**2,345,109**

Table 8: Total Cost vs FY

7.1.2.7 Cost changes between this schedule and the CD-1 schedule

The Total Cost difference between the Lehman CD1 review and the Current WBS is +$116k. The majority of this cost differential comes from a number of small items that had been mistakenly deleted from the previous frozen version of Open Plan.

7.1.2.8 Installation:

The installation plan for this subproject is captured in BTeV document #1207. The plan is to roll the magnets into the C0 Collision Hall at the first available shutdown after they are declared ready for installation. The installation of the beryllium beam pipes will probably be delayed until the FY09 summer shutdown in order to protect these delicate components. The Vertex Magnet or either Toroid assembly can be rolled into the C0 Collision Hall in any convenient 5 day Tevatron shutdown or maintenance period.

7.1.3 Response to CD-1 recommendations.

- There were no CD-1 recommendations for the WBS1.1 subproject.
- Nevertheless, as a result of the general CD-1 recommendation to reevaluate the overall BTeV spectrometer installation schedule, a careful examination of the schedule for the installation of the WBS1.1 components has resulted in a more conservative float in the WBS1.1 Open Plan schedule.

7.2 Schedule for Pixel Detector (WBS 1.2)

7.2.1 Introduction

7.2.1.1 Description

WBS 1.2 covers all the work related to the construction of the BTeV pixel detector. The BTeV pixel vertex detector consists of 30 stations. Each station is split into two halves: left and right. Each half station will be made up of two half-planes. Each half-plane will have detector modules mounted on both sides of a substrate made out of Thermal Pyrolytic Graphite (TPG). On one substrate, the modules will have the narrow pixel dimension lined up in the x-direction. On the other substrate, the modules will have the narrow pixel dimensions lined up in the y-direction. The pixel module is the basic building block of the pixel detector. Each module consists of a single piece of silicon sensor that is bump-bonded to a number of readout chips. Underneath the readout chips is glued a high density interconnect (HDI) flex circuit which carries the data and control I/O and power lines between the module and the pixel data combiner board (PDCB). The modules come in 4 different sizes. In total, there will be 1380 modules and 8100 readout chips. The total active area of the detector is about $0.5m^2$ and the total number of pixels will be 23 million. To bring signal out, the HDI will be attached to a pixel interconnect flat cable (PIFC). The pixel detector will be sitting in the beam vacuum. To protect against wake field production due to the interaction of the beam with the detector and the vacuum vessel, some RF shield in the form of a number of small diameter wires or thin strips will be installed between the colliding beams and the detector. To take the signal out of the vacuum vessel, we will use large feedthrough boards (FTB) made out of multilayer printed circuit boards. The vacuum system will consist of a number of cryopanels inside the vacuum vessel with liquid N_2 flowing through them and the liquid Helium cryopumps. On average, the power dissipated is about $0.5W/cm^2$ giving a total of 2.5 kW for the whole pixel detector system. The operating temperature of the detector is about -5^0C. Cooling of the detector is provided by the liquid nitrogen lines using the excellent thermal conductivity of the TPG to get to the required temperature. Nominally, the pixel detector will be placed at 6 mm from the beams. During beam refill, the two halves of the detector will be moved away to about 2 cm from the beams. When the beam is stable, the detectors will then be moved close to the beam for data taking. A system of 8 actuators and motion sensors will be needed.

7.2.1.2 Staging

The pixel detector will be installed in its entirety in Stage 1. The pixel detector is central to BTeV's physics reach. It provides the tracking and vertex reconstruction capability needed to do B physics and it is the input to the BTeV Level 1 Detached Vertex Trigger.

At the CD-1 Lehman review, it was suggested that only part of the detector (1/2 of the stations) could be installed. This proposal was reviewed. However, after consideration it was decided that the pixel detector will be installed as a complete, final unit with all stations assembled and tested inside the vacuum vessel. Installation of the pixel detector has to happen before the forward tracking stations 1-6 can be installed. Conversely, to remove the pixel detector will involve a reverse process, namely that the forward tracking stations that have been installed need to be removed first. This poses serious potential problems and risks of damaging the forward tracking stations. It will also lead to a long shutdown of the machine. So, after careful evaluation, we have decided not to pursue the staging option for the pixel detector. Rather, we will put our effort and assign resources to guarantee the completion of the pixel detector on schedule.

7.2.2 Project Flow & Cost

7.2.2.1 Methodology

We define the Work Breakdown Structure for the pixel project to an appropriate level for management of the project, typically to level 7. For each task, the duration is estimated based on prototypes, prior experience with previous projects/experiments, communication with vendors, and experience with similar projects. Dependence on other tasks are identified. The M&S cost is estimated, based on vendor quotes/budgetary estimates, prototype experiences, and cost of previous experiments using similar items. Labor resources needed are likewise engineering estimates using a bottoms up approach based on experience with prototypes and previous projects.

The completion date of the pixel detector is defined as a READY BY date which corresponds to the date when the pixel detector has been fully assembled and tested at SIDET and ready to be shipped to CZERO for installation. The Installation Subproject (WBS1.10) which works out an installation schedule for the whole experiment, provides us with a NEED BY date which corresponds to the date by which the pixel detector will be needed for installation. The TOTAL FLOAT of the pixel subproject is given by the difference between the READY BY and NEED BY dates.

The NEED BY date is determined by the anticipated beginning of the shutdown of the Tevatron in 2009 (August 1, 2009). The NEED BY date has been set to be August 18, 2009. For comparison, the corresponding dates that we presented at the DOE CD1 review were June 1, 2009 (beginning of FY09 shutdown) and May 1, 2009 (pixel detector READY BY date) respectively.

7.2.2.2 Flow Diagram

The basic building block of the pixel detector is a module, which is composed of a pixel sensor bump-bonded to a number of pixel readout chips. Underneath the readout chips, a high density flex cable (HDI) will be glued. The readout chips will be wire-bonded to the HDI and the latter will carry all the signal, control, and power lines from the pixel module to the DAQ system. The HDI will in turn be attached to a pixel interconnect flex cable (PIFC). All of these individual components will be tested before assembly. Once assembled, the pixel modules will undergo initial functionality tests followed by burn-in testing. The modules that pass the burn-in testing will then be mounted on a support substrate made out of thermal pyrolytic graphite (TPG) to form a pixel half-station. Next, all modules on a half-station will be fully tested for electrical and readout problems. Before assembly, each substrate will be tested for mechanical tolerances and thermal properties. A separate cooling test will be performed to ensure that the pixel half-station achieves the designed operating temperature. During this process, all assembly and alignment parameters will be recorded in a database.

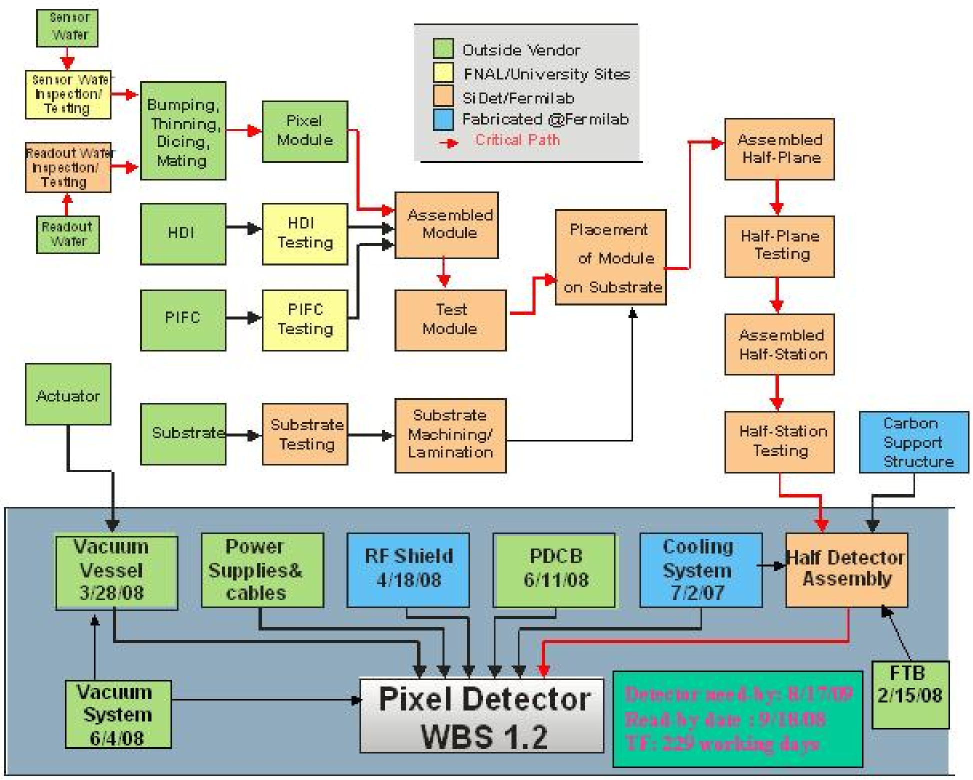


Figure 22: Process flow diagram for WBS1.2. The critical path for the project is marked in red. The detector READY BY date is September 18, 2008 and the NEED BY date is August 17, 2009 giving a total float of 229 working days. All the ancillary systems have a float bigger than 250 days.

The pixel stations will next be mounted to a carbon fiber support half-cylinder to form a half-detector. During this step, the position of each pixel half-station will be aligned and the information will again be recorded in a database. Once the half-detector is fully assembled, each half-station will be tested and read out. This testing will be repeated after the half station is inserted into the vacuum vessel at SIDET.

When both half-detectors are inserted and all cables and connections inside the vacuum vessel are properly installed, connected, and tested, the vacuum vessel will be closed. Before transporting the vessel from SIDET to C0, a number of system tests will be performed. These include both electrical/electronics and mechanical system tests (cooling, vacuum, and positioning). When the pixel detector has passed all these tests, it will be ready for installation (see section H below).

Figure 22 shows the flow diagram for construction of the pixel detector. The major components that will be needed to build the detector are shown in the figure. Some of these components will be fabricated at outside vendors. These include the pixel sensors, pixel readout chips, HDI, TPG, HDI etc. The pixel sensor wafers and the readout wafers, after tested at Fermilab and university sites, will then be sent to another vendor for flip-chip assembly (detector hybridization). The product of this process will be the pixel modules, which will then be tested and then glued to the HDI at the Fermilab Silicon Detector Facility (SIDET).

The final detector assembly will also be done at SIDET, which has excellent equipment, a talented and experienced technical crew and huge capacity to assemble and test silicon detectors. Ancillary systems such as the vacuum, cooling, positioning, vacuum vessel, power supplies, cables etc will be procured/built in industry. Since Fermilab Lab 3 has years of experience in building carbon fiber structures, all the carbon fiber related work (e.g. carbon fiber support structure) will be done at Fermilab. These systems will only be needed during the last stages of the detector assembly or be installed directly at CZERO. On the other hand, the fabrication of the pixel modules, their assembly and testing, and placement on the TPG substrates are a series of consecutive activities that represent the longest path (duration) through the project. These activities are the critical path of the construction of the BTeV pixel detector.

Table 9 lists the major construction milestones for the pixel detector. For comparison, the current and the old dates that were presented at the DOE CD1 review are shown together in this table. By moving forward the major procurement that includes the sensors, pixel readout chips, and detector hybridization, we will finish the construction of the pixel detector in September 2008. The total float is 229 working days compared to 63 days for the CD1 review.

Our old schedule, as noted by the reviewers in the CD1 review, was constrained by the funding profile and not by technology. We followed their recommendations to add six months to the total float. Moreover, we have revised our schedule based on the suggestions of the reviewers to allow:

a) a total duration of 18 months between the start of the production detector hybridization and the completion of the pixel detector modules delivery and testing;

b) a total duration of 30 months between the start of the production detector hybridization and the completion of the pixel detector assembly.

The revised schedule was achieved by allowing more funds in FY05 and FY06, by combining the preproduction and production steps for sensors, pixel readout chips, and detector hybridization. We have also discussed with the Procurement Department on various issues and steps to speed up the procurement of key elements for the detector. The current schedule also include these changes

Milestone	CD1 date	Current date
PO for Production sensor	Feb 2006	October 2005
PO for production readout chips	July2006	November 2005
PO for detector hybridization	Feb 2007	April 2006
Start of pixel station assembly	Nov 2007	April 2007
All pixel detectors delivered & tested	Mar 2008	October 2007
Pixel modules completed	May 2008	December 2007
Pixel detector ready for installation	Feb 2009	September 2008
Pixel detector NEED by date	May 2009	August 2009

Table 9: List of major milestones for WBS1.2. The CD1 date column lists the dates that were presented at the CD1 review. The current date column gives the corresponding new set of dates from our revised schedule.

7.2.2.3 Labor Profile

Figure 23 shows the labor profile per fiscal year, without contingency, in units of FTE (set to be equal to 1768 working hours). The total labor needed is estimated to be 114 FTE. The peak labor needed will be about 38 FTE in FY07. Figure 24 shows the labor resources that will be needed per fiscal year. In total, we will need 51.1 FTE physicists (including postdocs and graduate students), 28.6 FTE engineers (including electronics/electrical, mechanical, and software), and 33.4 FTE technicians.

Labor contingency is estimated to be 39.1 %. This is supposed to cover both additional labor resources and stretching-out of task durations.

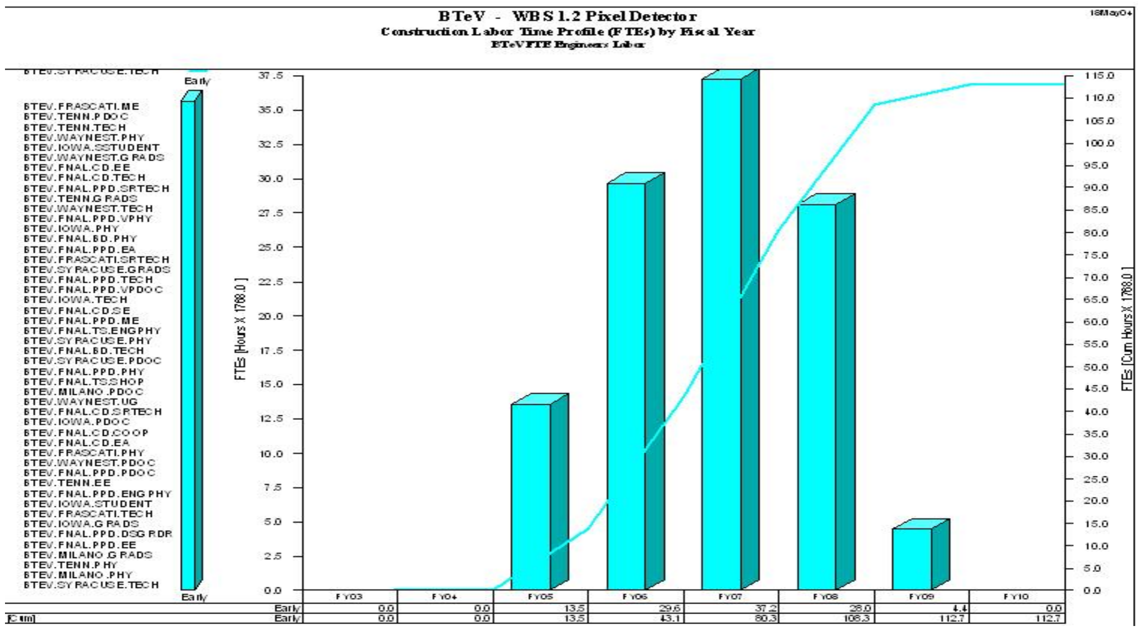


Figure 23: Labor profile for WBS1.2 per fiscal year in units of FTE. No contingency is included in this profile.

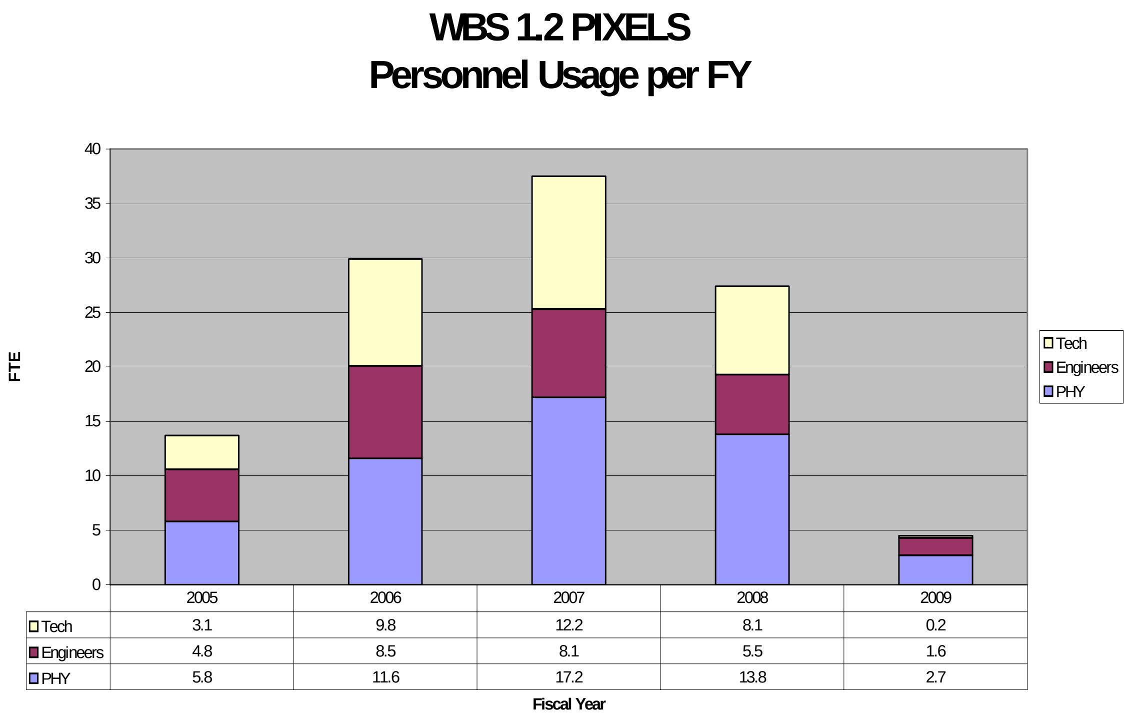


Figure 24: Personnel usage per fiscal year for WBS1.2

7.2.2.4

Cost Profile

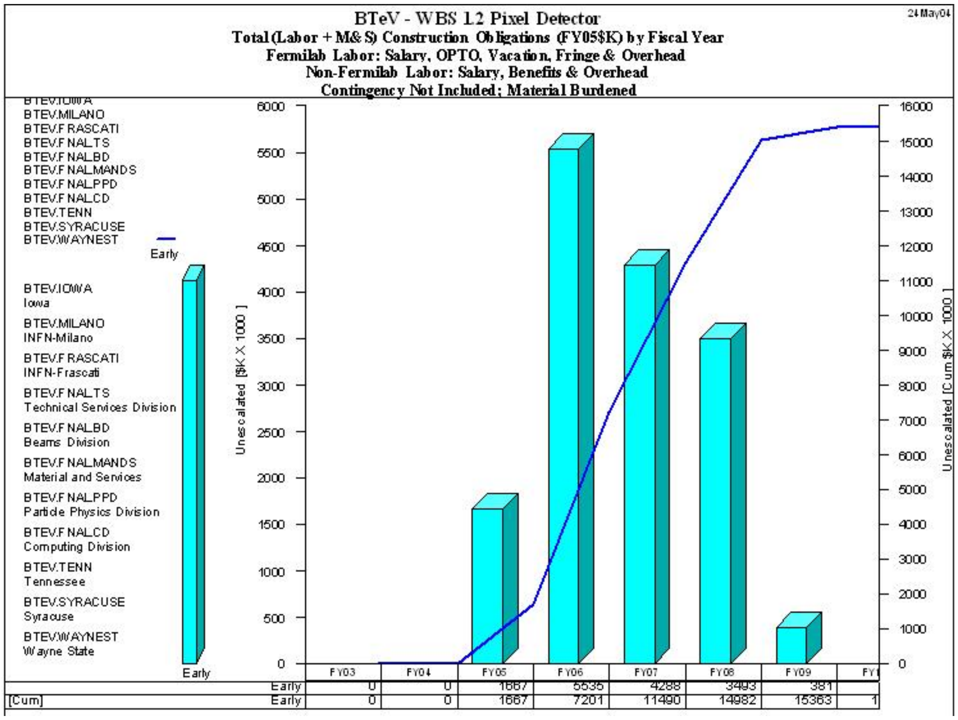


Figure 25: Cost profile for WBS1.2 without contingency.

Figure 25 shows the cost profile for the pixel project without contingency. Figure 26 shows the total M&S cost. Figure 27 shows the base cost, total cost (including contingency) and the given funding profile.

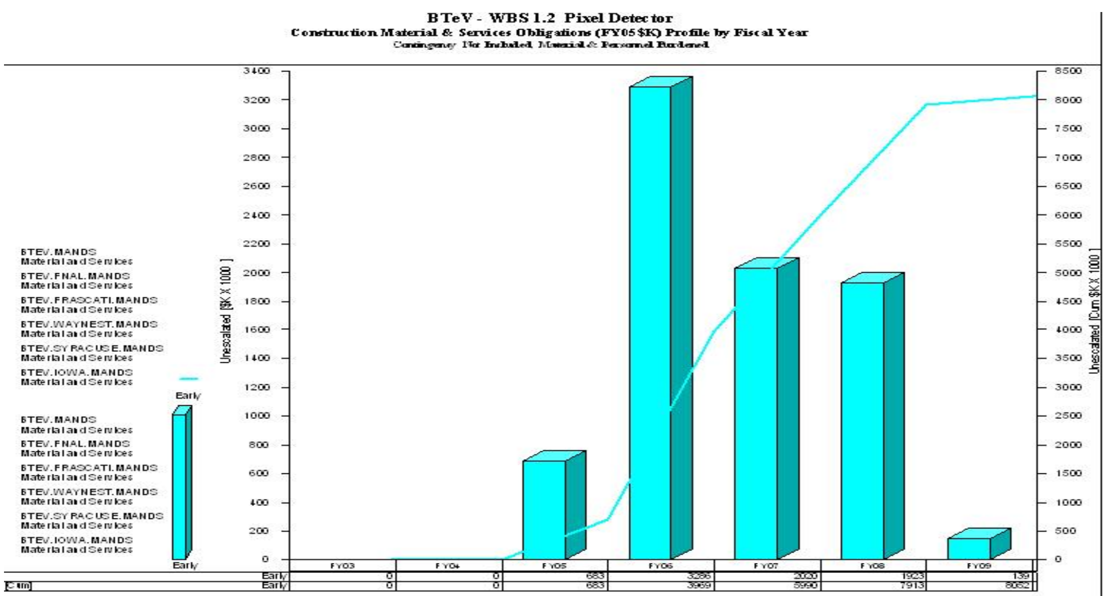
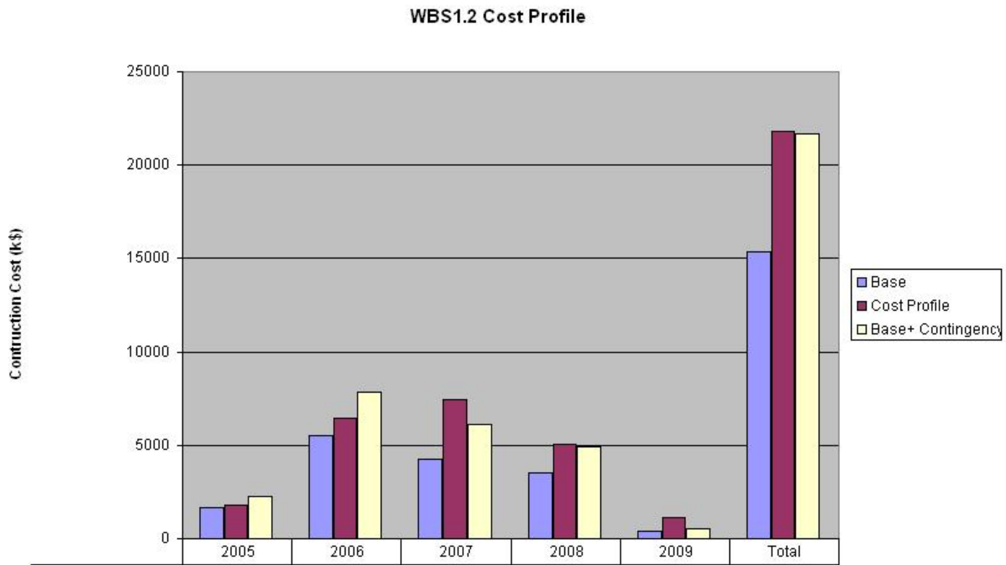


Figure 26: Total M&S obligation profile for WBS1.2. Contingency is not included.



	2005	2006	2007	2008	2009	Total
Base	1667	5535	4288	3493	381	15364
Cost Profile	1800	6450	7420	5030	1100	21800
Base+ Contingency	2283	7816	6133	4910	508	21650

Figure 27: Comparison with cost profile

7.2.2.5 Critical Path

As discussed in Section IIB, the critical path is the fabrication of the pixel modules, the placement of the assembled and tested modules on the TPG substrates to form half-planes and stations, and the assemble of the half-stations on the carbon support structure to get to the final pixel half-detector. Figure 28 is a Gantt chart, showing the key activities and milestones on the critical path, their scheduled start and finish dates, and the total float. The float, as mentioned before, is the difference between the detector READY BY date (September 18, 2008) and the detector NEED BY date (August 18, 2009) which is equal to 229 working days.

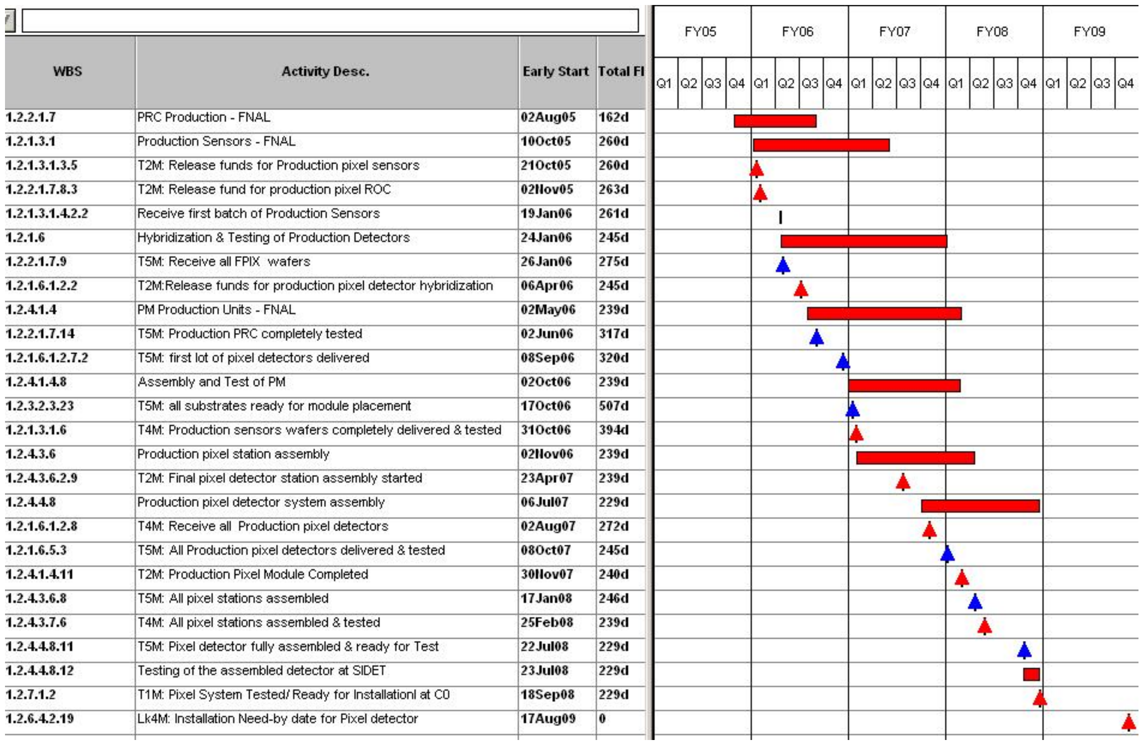


Figure 28: Gantt chart showing the activities on the critical path, their early start dates and the total float.

There is no explicit schedule contingency included in our schedule. A way to check the robustness of our schedule is to put in the schedule just before the key milestones a dummy task of nominally zero duration. By changing the duration to some number of days, we can mimic the effect on the schedule if a particular task is stretched out to a longer duration than expected. We have done this and typically, we have increased the duration of the L5 activities by 30% (about 30 to 100 working days depending on the task). Table 10 shows the effect on the key milestones by increasing the duration of a few key activities. We have also checked the effect on the schedule by increasing the substrate design/fabrication process by 50 days, and the cooling system construction by 50 days. No effect on the detector READY BY date has been observed.

Milestone	Normal schedule	Sensor delivery (+60d)	ROC procurement (+30d)	Hybridization delivery (+100d)	Pixel module assembly/testing (+50d)
PO for Pixel sensor	10/21/05	nc	nc	nc	nc

PO for ROC	11/2/05	nc	12/15/05	nc	nc
PO for hybridization	4/6/06	nc	4/24/06	nc	nc
Sensor wafers completely delivered & tested	10/31/06	1/29/07	10/31/06	nc	10/31/06
Receive all hybridized pixel modules from vendor	8/2/07	nc	8/20/07	12/26/07	8/2/07
Pixel assembly started	4/23/07	nc	5/1/07	7/27/07	4/23/07
Pixel modules completed	12/1/07	nc	12/10/07	3/11/08	2/14/08
All pixel stations assembled & tested	2/25/08	nc	3/4/08	5/29/08	5/2/08
Pixel detector READY for installation	9/18/08	nc	nc	12/10/08	11/12/08

Table 10: Schedule contingency check. By changing the duration of a few key activities, we can study the effect on the overall schedule. Nc means no change.

Activity ID	Activity Description	Early Start	Early Finish	Float
7.4.1	CD3 Milestone	01Oct04	01Oct04	245d
1.2.1.2.6	T4M: PO placed for Pre-Production Pixel Sensor	30Dec04	30Dec04	185d
2.1.4.8.2	Pre-Production PRC schedule contingency task	03Mar05	03Mar05	162d
2.1.4.8.3	T4M: PO placed for Pre-Production PRC	03Mar05	03Mar05	162d
1.2.1.2.9	T5M: Pre-Production Sensors received	01Jun05	01Jun05	185d
1.5.1.2	T4M: PO placed for preproduction pixel detector hybridization	30Jun05	30Jun05	185d
1.3.1.3.5	T2M: Release funds for Production pixel sensors	21Oct05	21Oct05	261d
7.2.2	T2M: PO Awarded: Pixel Sensors	24Oct05	24Oct05	266d
2.1.7.8.2	Production PRC schedule contingency task	02Nov05	02Nov05	245d
2.1.7.8.3	T2M: Release fund for production pixel ROC	02Nov05	02Nov05	245d
7.2.1	T2M: PO Awarded: Production pixel readout chip	02Nov05	02Nov05	335d
1.5.1.9	T5M: Receive Pre-Production pixel detectors at Fermilab	23Jan06	23Jan06	185d
2.1.7.9	T5M: Receive all FPIX wafers	26Jan06	26Jan06	275d
1.6.1.1.2	T4M: Ready for Detector Hybridization Production	07Apr06	07Apr06	245d
1.6.1.2.2	T2M: Release funds for production pixel detector hybridization	07Apr06	07Apr06	245d
7.1.1	T1M: PO Awarded: Production pixel hybridization	07Apr06	07Apr06	250d
1.3.1.5.3.7	Production sensor schedule contingency task	31Oct06	31Oct06	394d
1.3.1.6	T4M: Production sensors wafers completely delivered & tested	31Oct06	31Oct06	394d
1.6.1.2.7.5.4	Production pixel detector schedule contingency task	02Aug07	02Aug07	272d
1.6.1.2.8	T4M: Receive all Production pixel detectors	02Aug07	02Aug07	272d
4.1.4.10	T2M: Production Pixel Module Completed	29Nov07	29Nov07	240d
4.3.6.8	T5M: All pixel stations assembled	17Jan08	17Jan08	246d
7.1.2	T1M: Pixel System Tested/Ready for Installation at C0	18Sep08	18Sep08	229d
6.4.2.19	Lk4M: Installation Need-by date for Pixel detector	17Aug09	17Aug09	0

Activity ID	Activity Description	Early Start	Early Finish	Float
7.4.1	CD3 Milestone	01Mar05	01Mar05	143d
1.2.1.2.6	T4M: PO placed for Pre-Production Pixel Sensor	02Mar05	02Mar05	143d
2.1.4.8.2	Pre-Production PRC schedule contingency task	03Mar05	03Mar05	162d
2.1.4.8.3	T4M: PO placed for Pre-Production PRC	03Mar05	03Mar05	162d
1.2.1.2.9	T5M: Pre-Production Sensors received	01Aug05	01Aug05	143d
1.5.1.2	T4M: PO placed for preproduction pixel detector hybridization	30Aug05	30Aug05	143d
1.3.1.3.5	T2M: Release funds for Production pixel sensors	01Nov05	01Nov05	254d
2.1.7.8.2	Production PRC schedule contingency task	02Nov05	02Nov05	245d
2.1.7.8.3	T2M: Release fund for production pixel ROC	02Nov05	02Nov05	245d
7.2.1	T2M: PO Awarded: Production pixel readout chip	02Nov05	02Nov05	335d
7.2.2	T2M: PO Awarded: Pixel Sensors	02Nov05	02Nov05	259d
2.1.7.9	T5M: Receive all FPIX wafers	26Jan06	26Jan06	275d
1.5.1.9	T5M: Receive Pre-Production pixel detectors at Fermilab	22Mar06	22Mar06	143d
1.6.1.1.2	T4M: Ready for Detector Hybridization Production	25Apr06	25Apr06	233d
1.6.1.2.2	T2M: Release funds for production pixel detector hybridization	25Apr06	25Apr06	233d
7.1.1	T1M: PO Awarded: Production pixel hybridization	25Apr06	25Apr06	238d
1.3.1.5.3.7	Production sensor schedule contingency task	09Nov06	09Nov06	387d
1.3.1.6	T4M: Production sensors wafers completely delivered & tested	09Nov06	09Nov06	387d
1.6.1.2.7.5.4	Production pixel detector schedule contingency task	20Aug07	20Aug07	260d
1.6.1.2.8	T4M: Receive all Production pixel detectors	20Aug07	20Aug07	260d
4.1.4.10	T2M: Production Pixel Module Completed	07Dec07	07Dec07	234d
4.3.6.8	T5M: All pixel stations assembled	28Jan08	28Jan08	240d
7.1.2	T1M: Pixel System Tested/Ready for Installation at C0	18Sep08	18Sep08	229d
6.4.2.19	Lk4M: Installation Need-by date for Pixel detector	17Aug09	17Aug09	0

Figure 29: Views from OPENPLAN showing the effect of CD3a approval. The top view (a) assumes that CD3a date to be October 1, 2004. The bottom view (b) moves the CD3a date to March 1, 2005.

7.2.2.6 OBROWSER Views

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total Cost ($)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.2.1	Sensors and Pixel Detector Hybridization	2,244,262	47	32	3,251,349	604,896	2,494,553	148,932	2,968	0	3,251,349
1.2.2	Pixel Detector Electronics	4,180,018	37	39	5,741,872	740,583	1,774,960	1,060,929	2,165,400	0	5,741,872
1.2.3	Mechanical Cooling and Vacuum System	4,551,504	46	38	6,438,543	361,422	2,391,748	2,342,369	1,343,005	0	6,438,543
1.2.4	System Integration & Testing	3,587,917	48	47	5,272,247	386,273	961,807	2,389,974	1,207,973	326,219	5,272,247
1.2.5	Pixel Detector Subproject Management	799,673	23	18	945,962	189,949	192,976	190,706	190,706	181,625	945,962
1.2	**Subproject 1.2**	**15,363,375**	**43**	**39**	**21,649,973**	**2,283,124**	**7,816,045**	**6,132,910**	**4,910,051**	**507,844**	**21,649,973**

Figure 30: OBROWSER view showing the total construction cost per fiscal year.

7.2.2.7 Cost changes from CD1 review

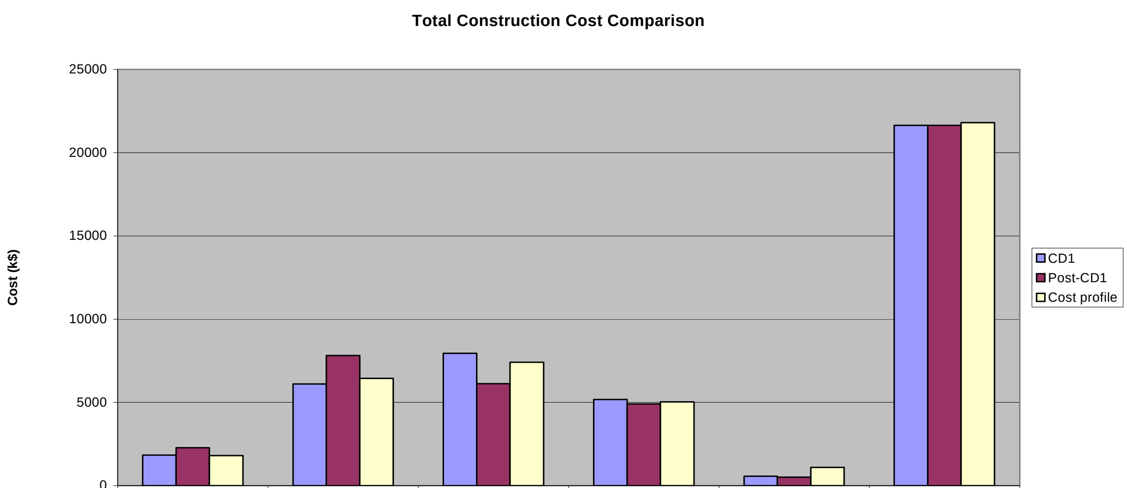
Figure 31 gives the total construction cost for WBS1.2 rolled up to L3. The base M&S cost is $8.05M, labor cost is $7.31M, contingency is $6.29M to give a total construction cost of $21.65M. For comparison, the corresponding numbers presented at the CD1 review were: base M&S cost $8.00M, labor cost $7.45M, contingency $6.20M with a total of $21.65M. The small changes in the M&S cost are mostly due to the fact that we have changed our plan to have the assembly of the HDIs done in industry instead of in-house and have increased by 10% the number of HDIs to be procured (take into account yield during assembly). The change in labor cost reflects also this change. By combining the preproduction and production steps of the sensor, readout chip, and detector hybridization, we have reduced slightly the labor cost but have added more to the labor contingency. We have also added more labor resources and contingency to the System Integration and Testing (module, station, and final detector assembly and testing).

BTeV - WBS 1.2 Pixel Detector
Total Construction Obligations in FY05$
Fermilab Labor: Salary, OPTO, Vacation, Fringe & Overhead
Non-Fermilab Labor: Salary, Benefits & Overhead
Material Burdened

Activity ID	Activity Description	Material & Services Cost	Labor Cost	Base Budget	Labor Contingency ($)	Materials & Services Contingency ($)	Total Budget (Base + Contingency)
CONSTRUCTION							
		$8,052,078	**$7,311,296**	**$15,363,374**	**$2,861,706**	**$3,424,892**	**$21,649,972**
1 -- Sensors and Pixel Detector Hybridization							
		$1,933,520	**$310,741**	**$2,244,262**	**$98,295**	**$908,791**	**$3,251,349**
2 -- Pixel Detector Electronics							
		$3,361,328	**$818,689**	**$4,180,018**	**$316,890**	**$1,244,962**	**$5,741,871**
3 -- Mechanical, Cooling and Vacuum System							
		$1,876,404	**$2,675,099**	**$4,551,504**	**$1,021,602**	**$865,436**	**$6,438,543**
4 -- System Integration & Testing							
		$810,709	**$2,777,207**	**$3,587,917**	**$1,294,415**	**$389,914**	**$5,272,246**
5 -- Pixel Detector Subproject Management							
		$70,116	**$729,556**	**$799,672**	**$130,501**	**$15,787**	**$945,961**
6 -- BTeV Management & Inter-Subproject Link Milestones							
		$0	**$0**	**$0**	**$0**	**$0**	**$0**
7 -- DOE, Fermilab and BTeV Management Milestones							
		$0	**$0**	**$0**	**$0**	**$0**	**$0**

Figure 31: Total construction cost for WBS1.2.

Figure 32 compares the M&S cost profile that was presented at the DOE CD1 review with the current profile. The new M&S profile shifts the procurement of key and critical components (detector hybridization and substrate) to earlier dates, resulting in the shift of the peak M&S obligation from FY07 to FY06. Figure 33 shows the old total cost profile that was presented in DOE CD1 review and the present one.



	2005	2006	2007	2008	2009	Total
CD1	1832	6112	7951	5180	570	21645
Post-CD1	2283	7816	6133	4910	508	21650
Cost profile	1800	6450	7420	5030	1100	21800

Figure 32: Comparison of the CD1 M&S obligation profile with the present profile.

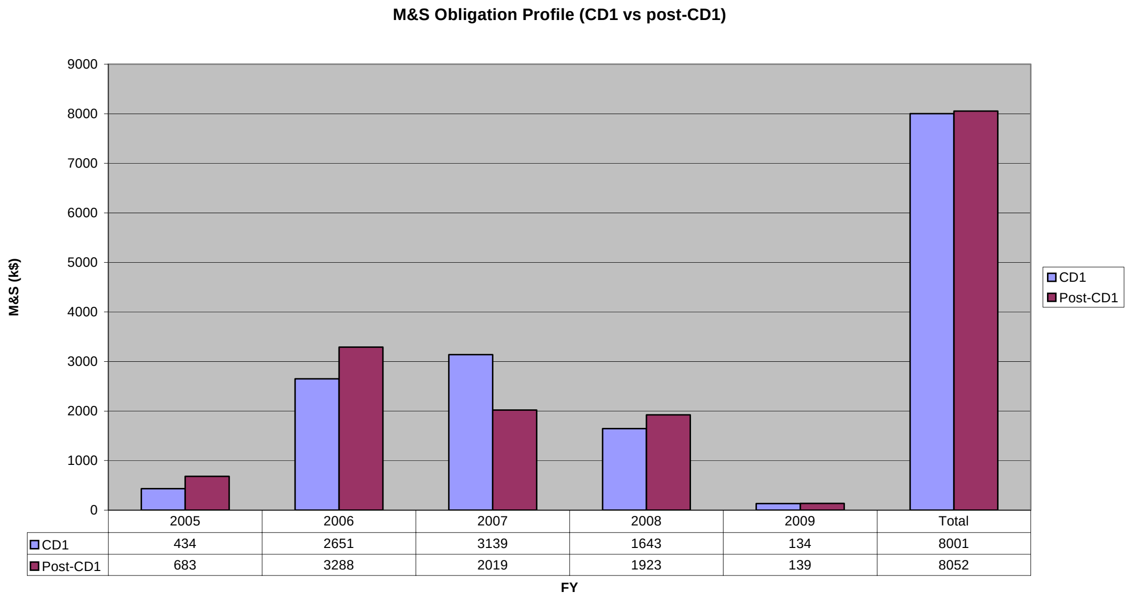


Figure 33: Pixel detector total construction cost comparison between DOE CD1 review and the present profile.

7.2.2.8 Installation

Preparatory work on infrastructure and services at C0

Prior to delivery of the pixel detector assembly to C0 a significant portion of the services infrastructure should be installed and tested. The cryogenic supply system should be installed and made fully operational, including all process controls external to the SM-3 magnet. Similarly all external vacuum system components should be installed and made fully operational and tested. The external motor drive system and the hydraulic lines, which connect to the actuator system on the pixel vacuum vessel will also, be installed and fully tested. All crates, electronics (PDCB and data links), slow control modules and cables, and power supplies should be installed and tested, including verification of each channel with a test pixel module, prior to connection of the installed detector to these services.

Transportation of the Pixel Detector to C0

Before leaving SIDET the detector will be fully assembled and tested, including the data and power cables that will be used to connect from the feed-through boards to the data combiner boards. Temporary end flanges will be mounted in place of the final vacuum windows and a full vacuum test will be performed. The entire assembly will be mounted on a transportation cart and the cables will be dressed and strain relieved to that cart. In total one full shift is required for this task.

Mechanical Installation of the Pixel Detector into the SM3 Magnet

The mechanical installation will proceed as follows:

- The detector will be unloaded from the truck onto the C0 assembly hall loading dock and moved to the assembly hall floor using the assembly hall crane. A trained crane operator will be required.
- The detector will be transported from the assembly hall to the experimental hall and prepared for insertion into the SM-3 magnet.
- Using a transportation fixture, the detector will be lifted and attached to overhead rails attached to the magnet. Note that the same rails may be used for the installation of the 1st, 2nd and 3rd straw stations.
- The detector will be rolled into the magnet, attached to the support brackets, and then disconnected from the rails. Details of this operation will be defined later, when a more detailed detector design will be available. The brackets will be installed and tested before detector installation.
- The temporary flanges will be dismounted and the end windows will be mounted in their places and connected to the rest of the beam pipe.
- Using support brackets, the pixel detector will be finally aligned and secured. Surveyors will be needed. It is expected that the precision of the final alignment of the vessel fiducials will be better than 250 microns.

This operation is estimated to take three days; one day for the move to the magnet the second day to complete the installation, and the third day for preliminary alignment.

Installation of the Pixel Detector Services

This phase of installation includes dressing of cables out of the SM-3 magnet and connection of the pixel services and cables to the pre-existing external infrastructure (installation of this equipment is described below). The operations involved are as follows:

- The detector cables will be routed out of the SM-3 magnet to the relay racks where they will terminate. The cables will be attached to the supports on the SM-3 magnet and the required clearance for the straw stations will be verified.
- The external cooling, vacuum, actuator lines, and power lines will be attached and tested.

This phase of the installation is anticipated to take 3 to 5 days to complete.

Final Pixel Electrical Connections and Functionality Tests

The final electrical connections at the relay racks will be done in concert with functionality testing of each module as it is integrated into the system. This is the procedure used by the collider detectors during hook-up of the Run II silicon detectors. A typical scenario might be that one DCB worth of cables are connected, followed by testing of those modules before additional cables are connected. In this way bad connections are rapidly identified and repaired before they are buried under the subsequently installed cable plant. An alternative scenario would be that a technician would install cables during the day shift and a group of physicist would do the testing and any required repairs during the evening shift.
In addition to the electrical hook-up and functionality tests, a final survey and alignment of the pixel detector to the Tevatron beam line must be performed prior to installation of the forward tracking stations which will block the line of site to the pixel vessel. This task concludes the work required prior to commencement of installation of the forward tracking stations.

For purposes of schedule planning we assume the duration of this effort to be 1 month, with any subsequent efforts included below in the system tests and full detector commissioning which are the natural evolution of this effort. The final survey and alignment of the detector to the beam line should take one day.

7.2.3 Responses to CD1 recommendations

The reviewers reported that the technical status and work plan is excellent ad that the technical status could allow faster ramp up to full production but the schedule is constrained substantially by limited funding profile.
Below is the list of recommendations and our responses:

a) Develop a more conservative schedule with significantly more float (≥ 6 months)
We have followed their recommendation. By moving a few procurements forward and move back the detector NEED BY date, we have achieved a float of about 11 months.
b) Evaluate options for relaxing the funding profile constraints to achieve a more conservative schedule
We agreed and this will be looked into globally across the whole BTeV project.
c) Evaluate the schedule and performance impact of significant staging options, e.g. ½ of the pixel readout planes.
While we believe that the experiment will work with about 60% efficiency with say ½ of the pixel stations, to complete the installation of the other half of the pixel detector will lead to a long shutdown, estimated to be about more than 6 months and with considerable

risk to the forward tracking stations (which need to be removed first before the pixel vacuum vessel can be taken out and later be re-installed). After careful consideration, we think that it is better to assign resources to guarantee the completion of the pixel detector on schedule and not pursue the staging option for the pixel detector.

7.2.4 BTeV Pixel Detector Risk Analysis

A “risk” is an event that has the potential to cause a wanted or unwanted change in the project. Here, we focus on “risks” to the BTeV pixel detector that are “unwanted”.
A risk is

- a definable event;
- with a probability of occurrence; and
- with a consequence or “impact” if it occurs.

Risks can affect the schedule, cost, scope (what the project finally has in it) or technical success (all requirements met) of the project. A measure of the severity of risk is **Severity = Probability x Impact.**

Following the guidance as outlined in BTeV-doc-1112, we have done an analysis of the pixel detector and identified the “risk events” as outlined as Table 11. Only events that have a Severity above 0.15 are listed. In Table 12, we give our risk mitigation plan.

Table 11: BTeV Pixel Detector Risk Listing

WBS Number	Risk Event	Probability	Impact	Severity
1.2.1.3.2	Vendors move from 4” technology to 6” technology. Takes a long time to understand the process and improve the yield	Moderate (0.3) (Best technology; with 6”, equipment should be more up to date)	High (0.5) (Schedule impact; vendor takes time to ramp up production capacity)	0.15
1.2.1.6.2	Our current bump bonding vendors not available to us any more or have unacceptable yield	High (0.5) (Latest technology; little experience with large scale production	High (0.8) (Severe cost increase and project slippage)	0.4
1.2.2.1.4	0.25mm CMOS process disappears before we go into production	Moderate (0.25) (Process below 0.25mm already exist)	High (0.8) (Schedule impact and technical performance may be affected; needs re-design)	0.20
1.2.4.1.1	None of the vendors can produce the multi-layer flex cables with acceptable yield; or the couple of vendors are too busy with orders from other HEP experiments.	Moderate (0.3) (While minimal technical problems are expected, we don’t know what will be the yield of large scale production)	High (0.5) (Overall project slippage and increase in cost)	0.15
1.2.3.8.2	We cannot achieve the vacuum required due to gas load much bigger than expected or there is not enough room to put in the big pumps or panels	High (0.5) (Some technical problems expected; cryopumps need to be custom made)	High (0.5) In order to make room for the pump-out ports or reduce outgassing, we may have to reduce the length of the detector; in the worst scenario, we may be forced to run the detector not in vacuum.	0.25

1.2.3.2.3	TPG substrate is fragile and may deform or break during assembly; flatness is also a concern	Moderate (0.3) (Experienced some problems during prototyping phase; but have a new way of encapsulation)	High Risk (0.5) (Impact of cost and schedule; may need many more parts than expected)	0.15
1.2.3.6.3	Problems with producing stable and reliable cooling line for LN2 with good thermal contact	Moderate (0.4) (Lots of brazed joints for the cooling blocks and clamped joints for the supporting Al ribs)	High Risk (0.4) We cannot operate at the temperature that we would like to have or we have to increase the material budget	0.16
1.2.4.3.2 and 1.2.4.3.3	The pixel temperature control, cooling, and vacuum system do not work as designed.	Moderate (0.3) (Complicated system with high interdependency and needs to be well controlled)	High Impact (0.8) We cannot build or operate the pixel detector as designed; overall cost increase and project slippage	0.24

Table 12: BTeV pixel detector Risk Listing with Mitigation Strategies

WBS number	Risk Event	Response/mitigation strategy
1.2.1.3.2	Vendors move from 4” technology to 6” technology. Takes a long time to understand the process and improve the yield	Work with multiple vendors. Keep in close contact with vendors to understand their future plans.
1.2.1.6.2	Our current bump bonding vendors not available to us any more or have unacceptable yield	Identify other vendors. We have kept close contact with ALICE, ATLAS and CMS and have information about their schedule and vendors.
1.2.2.1.4	0.25□m CMOS process disappear before we go into production	The best solution is to start production as soon as funding is available.
1.2.4.1.1	None of the vendors can produce the multilayer HDI’s with acceptable yield; or the couple of vendors are too busy with orders from other HEP experiments.	We need to identify other vendors and keep abreast with all the developments in electronic packaging. We have to follow the industrial trend but not lead it. We would learn from the current round of prototypes issues on yield and vendor reliability

1.2.3.8.2	We cannot achieve the vacuum required due to gas load much bigger than expected or there is not enough room to put in the big pumps or panels	We have a technical design of the vacuum system. Pump down and regeneration procedures have been worked out. The next step is to repeat the outgassing test with a full –size feed-through board and do prototype of the cryopump as soon as possible.
1.2.3.2.3	TPG substrate is fragile and may deform or break during assembly. Flatness of the substrate is also a concern.	We have developed an encapsulation process that improves the stiffness significantly. We are developing the proper procedures to handle the TPG. and conducting prototype placement tests to understand better how to assemble modules on TPG.
1.2.3.6.3	Problems with producing stable and reliable cooling line for LN2 with good thermal contact	Tests will be performed on full-sized prototypes. Analysis will also be performed to improve the brazing and clamping technique.
1.2.4.3.2 and 1.2.4.3.3	The pixel temperature control, cooling, and vacuum system do not work as designed.	We have put in our plan a system demonstrator program that will happen early in the construction to study this.

7.3 Schedule for RICH Detector (WBS 1.3)

7.3.1 INTRODUCTION

7.3.1.1 Description

WBS 1.3 covers the work related to the construction of the BTeV Ring Imaging Cherenkov (RICH) detector. This detector encompasses two systems sharing the same active volume: a mirror focused RICH, and a proximity focused liquid radiator RICH. The gas rich uses C_4F_8O as the radiator of choice, includes a low mass mirror segmented into tiles with low mass carbon fiber substrates and includes photosensitive detector array with active bandwidth in the visible wavelength interval. The baseline photon detector is the HAMAMATSU R8900-00-m16, with a 163 pixel pad HPD produced for this application by DEP as an alternative option. The liquid RICH includes a radiator vessel mounted on the detector entrance window, using C_5F_{12} as the radiator of choice and 4 planes of 3 inch phototubes as the photosensitive array. All the photon detector arrays are read out with custom made front end PCBs hosting custom made front end ASICS developed for our application by IDEAS, NO. We call these circuits front end hybrids. They are manufactured with conventional printed circuit board substrates (FR4), where IDEAS mounts and wire-bonds the front end ASICs. The advantage of using PMT and MAPMT photon detectors is that the signal shape is very similar. We will use the same

ASIC as the core element of the front end electronics. The geometrical constraints of the two systems are very different, thus we will customize the printed circuit boards used in conjunction with PMT arrays. The front-end hybrids provide parallel digital readout. Information for multiple hybrids are combined, stored and formatted into serial data streams multiplexer boards (FE MUX) that organize the communication with the remote data combiner boards (DCBs) with a general structure common to all the BTeV detector systems. Although the FE MUX have some elements unique to the RICH readout architecture, common features in the firmware and line drive elements between the RICH system and other components will make their design easier. A common strategy for high voltage and low voltage acquisition for the whole experiment will expedite the acquisition of these components and minimize cost.

7.3.1.2 Staging

The RICH detector will be installed into three main stages:

1. the RICH tank, including the liquid radiator vessel, mirror and top PMT array will be mounted first. The anticipated schedule for this event is the FY08 shut-down. Prior to this installation step, the RICH tank will be welded in the assembly hall, the front window will be installed as well as the liquid radiator vessel, the mirror system will be mounted and aligned, and the top PMT array will be mounted on the tank. Subsequently, the partially instrumented tank will be rolled into the collision hall.
2. the 2 MaPMT arrays will be assembled and tested at Syracuse and delivered to Fermilab well before the FY09 shutdown, when they are installed on the super-vessel. At this point the gas RICH is ready to take data.
3. the remaining PMT planes will be installed in a second stage, presently planned for the spring of FY10. Thus the liquid radiator system will be operational in a second stage of data taking of the BTeV detector.

This strategy gives a virtual certainty that the gas RICH will be constructed in a timely fashion and will be ready to take data at the anticipated starting time of the experiment. The construction schedule devised so far is robust against production delays, does not depend upon major acquisitions being undertaken in FY05 and is consistent with the funding profile expected for the experiment.

7.3.2 Project Flow & Cost

7.3.2.1 Methodology and “Ready by” and “Need by” dates

We define the Work Breakdown Structure for the BTeV RICH project to an appropriate level for the efficient management of the project, typically to level 5 or 6. For each task, the duration is estimated based on prior experience with the CLEO RICH detector or with our prototyping effort or with communications or quotations from vendors. All the major M&S acquisitions are backed up by recent quotations.

The floats in this project are defined by the READY BY dates determined for the stages described before by a careful analysis of the optimum installation staging of the other detector components of the BTeV experiment. The acquisition strategy has been carefully designed to maximize the floats in this scheduled, defined as the time intervals between the READY BY dates of individual detector components and the corresponding NEEDED BY dates. The critical NEED BY dates are 9/1/2008 for stage I, 9-11/2009 for stage II and 5/2010 for stage III described above.

Table 13 shows the relationship between the major "ready by" dates and "need by" dates.

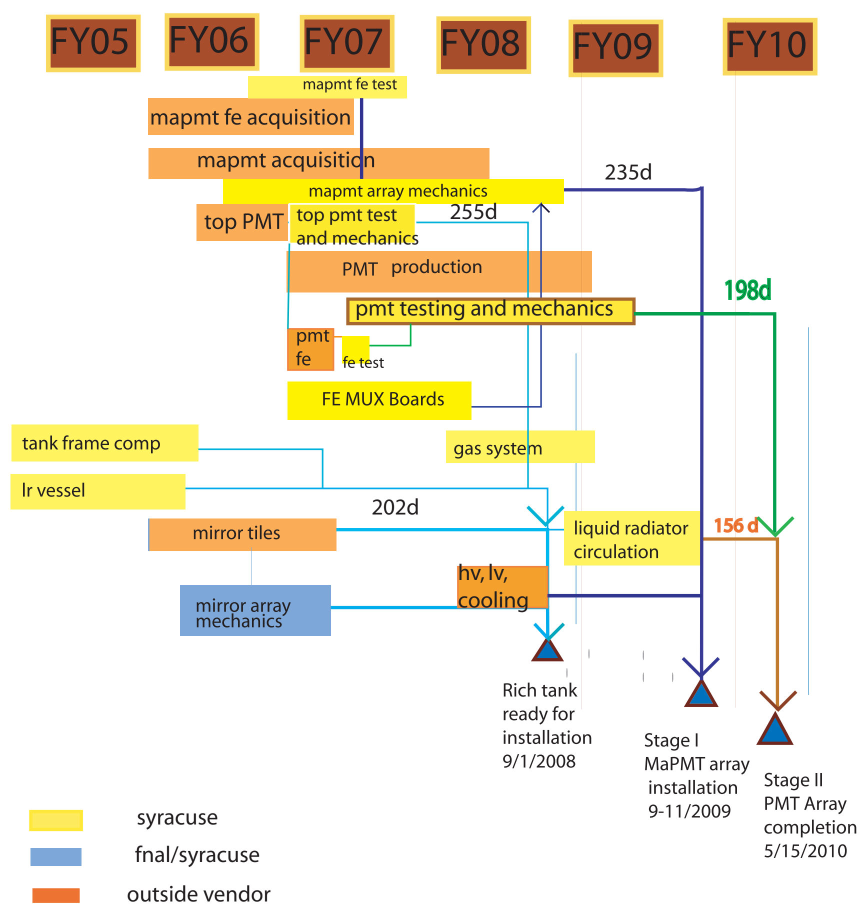
Table 13: "ready by" dates and "need by" dates for WBS 1.3

RICH (1.3) High Level	Ready by	Needed By
RICH Tank ready for installation	10/9/07	9/1/08
West MAPMT array ready for installation	5/13/08	9/21/09
East MAPMT array ready for installation	6/8//08	11/2/09
RICH (1.3) Low Level		
Bottom PMT array ready for installation	12/22/08	7/15/10
West PMT array ready for installation	3/31/09	7/15/10
East PMT array ready for installation	7/12/09	7/15/10
Gas purification system ready for installation	8/5/08	10/19/09
Liquid radiator circulation system ready for installation	9/29/09	6/1/10

7.3.2.2 Flow Diagram

Figure 34 shows a flow diagram of the tasks to be completed to implement the full RICH detector. Activities flow along several parallel lines whose timing is largely determined by the funding profile

Figure 34:Flow diagram of the RICH detector construction



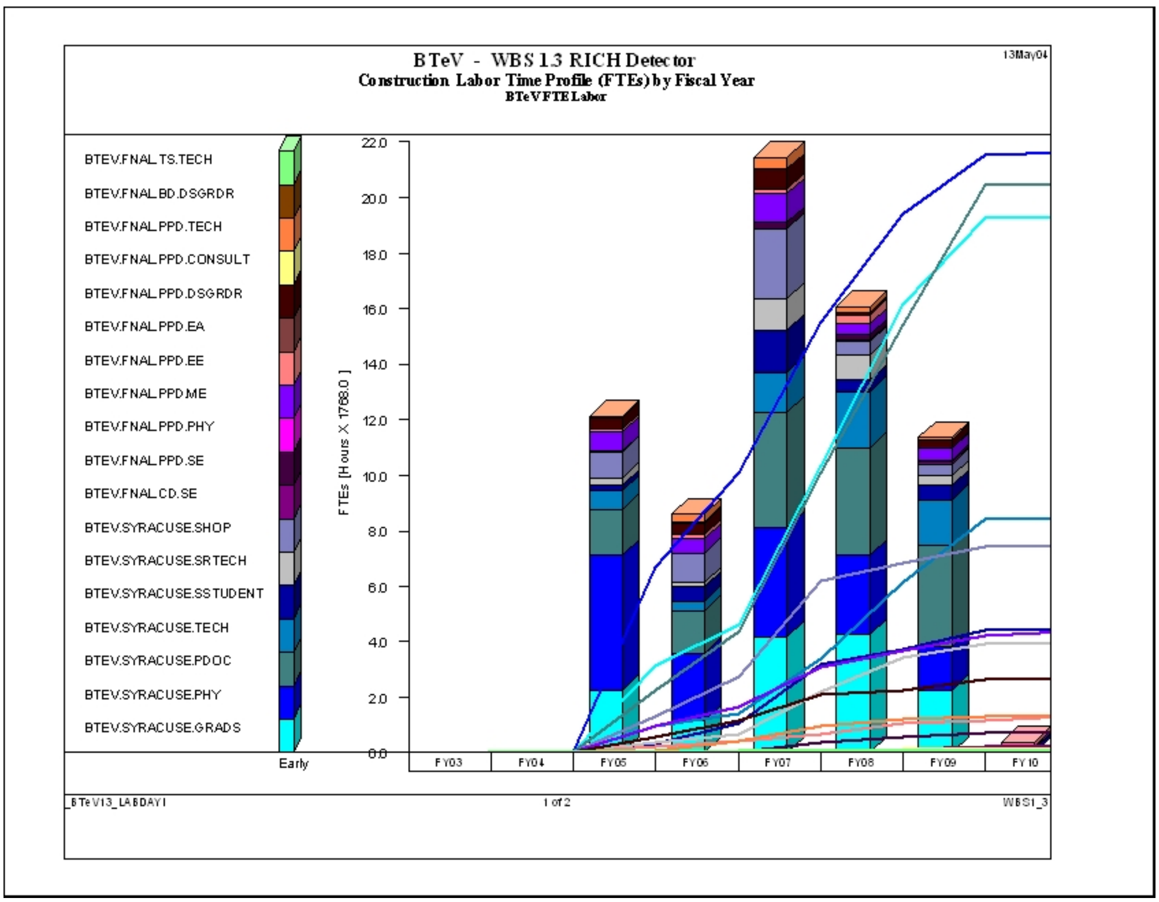
All the major acquisitions are started in FY06 to be compliant with the expected funding profile. FY05 is devoted to establish the test infrastructure, implement a liquid radiator prototype system to be tested in the beam and fabricate some of the components of the mechanical infrastructure.

Major construction starts in FY06, along several parallel lines: MAPMT production, PMT production, front end electronics and mirror tiles and mechanics. The pace of these parallel paths is largely set by funding and priority has been given to the items that are needed earliest. All the major acquisitions are completed relatively early in the course of this project. The only acquisition stretched in time, because of our goal to be consistent with the funding profile, is the PMT acquistion. This is not only consistent with our staged installation, but also capitalizes on the fact that the PMTs that we are planning to acquire are “off-shelf” devices, available from four different vendors (Hamamatsu, Burle, Photonis, ElectronTubes). Thus they are the items for which availability is more readily established. Therefore, our schedule not only features a very conservative “float margin”, but also has the smallest floats for the most conventional items needed, making our time projections extremely reliable.

7.3.2.3 Labor Profile

Figure 35 shows the labor profile for the BTeV RICH project, without contingency, in units of FTE (set to be equal to 1768 working hours).

Figure 35: Labor profile (FTE) for the RICH Project



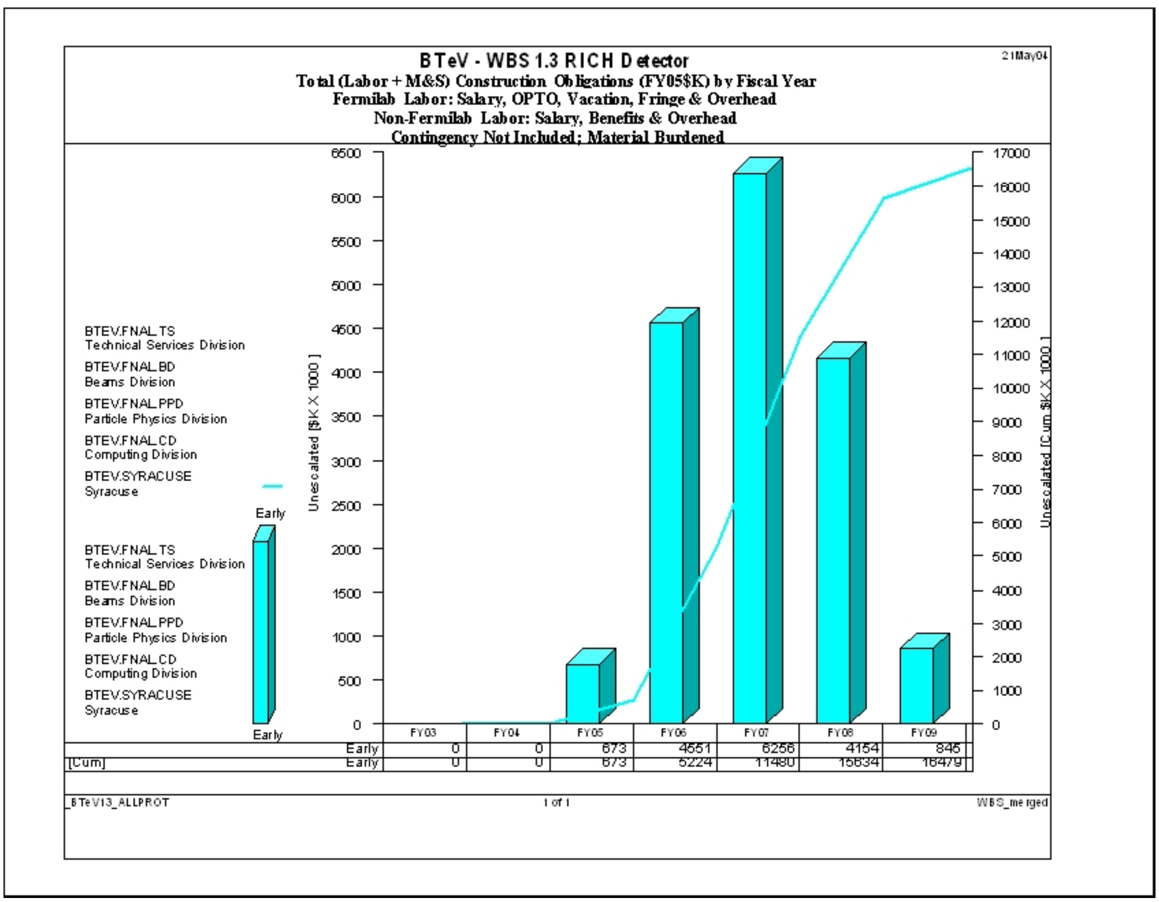
In total, we need 45.2 FTE physicists (faculty, postdocs, graduate students), 16 FTE technical staff (technicians, senior technician, shop), 5.7 FTE engineers (mechanical, software, electrical).

Labor contingency is estimated to be 28%. This covers both additional labor resources and stretching out of task durations. If unforeseen delays occur, most of the tasks can be expedited by making the test or assembly jobs more "parallel" with very modest expenditures. For example, we can easily duplicate the photon detector testing or assembly stations.

7.3.2.4 Cost Profile

Figure 36 shows the spending profile compared to the projected funding profile. Contingency is included. The material contingency is estimated with a bottom-up approach, and averages 37%, the labor contingency, also estimated with a bottom-up approach, averages about 28%. The spending profile is compared with the projected funding profile available to this project and a very reasonable match is shown.

Figure 36: Spending profile (fully burdened, contingency included) compared with the funding profile



Needed	673	4551	6256	4154	845
Projected	719	4463	5761	4300	1197

7.3.2.5 Critical Path

Most of the activities have a significant amount of floats with respect to their READY BY date. In the present strategy, the critical path is represented by the completion of the liquid radiator circulation and monitoring system. This is a conventional fluid recirculation system, engineered from well known components. Its construction is delayed to devote financial and manpower resources to less conventional components. The schedule allows for great flexibility in the delivery date of all the major components without adversely affecting our ability to deliver the subsystems expected at all the 3 stages of installation. As the project is implemented along several parallel paths, the floats shown in Figure 34 give a good indication of the degree of flexibility allowed by our construction strategy. Our original schedule was recognized to be realistic by our CD1 review committee and this staged schedule is by far more conservative.

7.3.2.6 OBrowser View (Total Cost by Subproject)

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.3.1	Multi-anode PMT Photon Detectors (MAPMTs)	5,397,123	39	32	65,863	1,888,597	3,603,375	1,961,385	0	0	7,519,220
1.3.2	Photomultiplier Tubes (PMTs)	1,175,253	25	24	0	461,161	80,585	654,578	272,009	0	1,468,332
1.3.3	Photon Detector Electronics	1,655,334	48	43	131,558	1,017,170	1,222,346	69,315	0	0	2,440,390
1.3.4	Mirror Arrays	785,403	53	34	0	893,103	276,167	0	0	0	1,169,270
1.3.5	Mech Gas Liquid & Related Systs	1,442,645	28	26	216,547	190,001	854,041	97,685	472,518	0	1,830,792
1.3.6	Power Monit Cooling & Related Systs	784,049	25	20	10,545	0	60,308	854,348	47,256	0	972,457
1.3.7	RICH Detector Install & Integ & Test	385,464	21	29	159,395	3,010	306,417	19,232	2,958	0	491,012
1.3.8	RICH Detector SW	198,110	46	33	0	0	56,275	194,611	17,320	0	268,206
1.3.9	RICH Detector Subproject Management	272,452	20	20	88,690	98,362	61,186	36,930	41,775	0	326,943
1.3	Subproject 1.3	12,095,832	38	28	672,598	4,551,404	6,520,698	3,888,084	853,837	0	16,486,622

Table 14: RICH Costs by fiscal year (FY05 $)

7.3.2.7 Cost Changes since CD-1 Review

The staged installation redistributes cost among the fiscal years, but does not affect the overall cost that has already been validated during the CD1 review.

7.3.2.8 Installation

Most of the assembly and test work for the BTeV RICH detector will be performed at Syracuse. The most extensive period of time that we will need to spend in the assembly hall is prior to the rolling of the partial instrumented tank in the C0 collision hall. A short summary of the steps that need to be undertaken in the assembly hall is:

1. welding of the tank component
2. front window and liquid radiator vessel installation
3. beam pipe insertion and beam pipe to window seal
4. mirror assembly and preliminary alignment of window tiles
5. top PMT installation
6. expansion volume installation

Details of each of these steps are given in the installation document. These tasks are expected to be completed prior to the FY08 shut-down.

The second installation step involves shipping the MAPMT arrays from Syracuse to Fermilab, a quick integrity check in the assembly hall and the mounting of these arrays in C0. These tasks are expected to be completed during the FY09 shutdown. The remaining PMT arrays are expected to be installed and commissioned in Spring of 2010.

7.3.3 Response to CD1 review

The CD1 review of the RICH detector project was generally very positive. Two recommendations were made:

1. gain experience with hadron collider environment by taking data in C0
2. measure neutron background in C0

The subsystem that is more vulnerable to background is the liquid radiator RICH. We are planning a beam test of a prototype of this system in FY05 and we are interested in any opportunity of exercising this system that will be available to us. We are also planning to pursue more extensive background simulations and we hope to validate these studies with experimental data from CDF.

7.4 Schedule for Electromagnetic Calorimeter (WBS 1.4)

7.4.1 Introduction

7.4.1.1 Brief Description

The electromagnetic calorimeter (EMCAL) consists of 10,100 lead-tungstate (PWO) crystals of identical tapered rectangular shape and the size is 220 mm in length and 28×28 mm^2 in cross section at a larger end and 27.2×27.2 mm^2 at the narrower end. They are wrapped by a Tyvek sheet to improve the collection efficiency of scintillation light. The scintillation light from each of these crystals is detected by a one-inch diameter photomultiplier tube (PMT) of length about 60 mm. These PMT's have 5-6 dynodes, requiring 6-7 high voltages ranging from 200 to 1000 V. We will use a single set of 6-7 HV power supplies to provide these 6-7 different voltages for a group of about 100 PMT's. We will use a ribbon cable and daisy chain groups of PMT's to deliver HV's.

Signal from the PMT's are carried by coaxial cables of 2-4 m in lengths to front-end boards (FEB's) in subracks near the detector. The FEB's consist of multi-range ADC's called QIE9's and supporting electronics to digitize the signal with more than a 10^5 dynamic range.

Since PWO crystals are too fragile and break if they are stack up one on top of another, we will fabricate a square cell structure using aluminum strips, which are span in a strong frame. We will insert a combination of a PWO crystal and a PMT, which are glued together, into its own cell.

An optical fiber carrying light from LED-based light pulser system will be attached to each crystal near the PMT. This will be used to test functionality of the PMT and PWO crystal during installation, and to calibrate their sensitivity after operation starts.

7.4.1.2 Definition of Staged Detector

In order to produce an EMCAL with a sufficient number of PWO crystals to be able to study interesting physics by 2009, we plan to stage the construction of EMCAL. The first-stage EMCAL will have about half of 10,100 crystals. We have more than a year of schedule float (229 days) with this 50% detector. However, this detector will provide about 60% of acceptance for many of interesting physics topics using final states containing π^0 and η. This is accomplished by strategically populating those 50% of the crystals. If everything goes well, many more than 50% of the crystals will be in the support structure when the first run starts.

7.4.2 Project Flow & Cost

7.4.2.1 Detector "Ready By" and "Need By" dates

Table 15 lists the dates that major components are ready to be installed, and the dates that they are needed for timely completion of BTeV.

	Ready-by dates	Need-by dates	Floats
Stage 1 EMCAL	Sept. 2, 2008	Aug. 1, 2009	229 days
100% of crystals-PMT's	Sept. 24, 2009	July 1, 2010	191 days

Table 15: "Ready by" and "Need by" dates for EMCAL

7.4.2.2 Description of how project will work

We will start with the front-end chip, QIE, production in FY05 mostly because the 0.8μm technology, which is used in the current design, may be obsolete in the not-so-distant future. We will delay the front-end board design until FY07 since we don't need these boards for a while, and this will match the funding constraints better.

In FY06, we will start Chinese crystal production. Since the Chinese vendor does not have large production capacity (~130 crystals/month), it is beneficial to them and us to produce crystals over longer period. They will be tested by our Chinese colleagues at Nanjing, Shandong and USTC before they are sent to the US. We will measure the light outputs, their uniformity over the lengths of the crystals, and radiation sensitivities. Once the crystals are shipped to the US, we will visually inspect all crystals to make sure they are not cracked or otherwise physically damaged. Sample of crystals will be measured to make sure that they meet our specs, and there in no significant differences between the US and Chinese measurements.

In FY07, we will start Russian crystals. They have so much capacity (1000/months) to produce their share of crystals in 5 months (10 months for all BTeV crystals), but to match the funding profile better, we will acquire ~5000 crystals over two years (230/month). It is likely that before FY07, they are busy with CMS endcap crystals, although CMS may forgo endcap calorimeter, in which case the Russian vendor may be able to produce our crystals earlier. Russian crystals will be tested by our IHEP colleagues, but otherwise treated in a similar fashion as the Chinese crystals.

We will also start PMT production in FY07. Acceptance tests will be done in the US.

Each of the crystals will be glued to a PMT, and tested again using a light pulser to make sure that the glue joint is good. They will be stored until the support structure is ready in the beginning of FY08.

The parts for the mechanical support structure will be acquired in FY07, and will be assembled after the summer 2007 shutdown period when the Assembly Hall in the C0 building has enough space. Before then, the muon toroids occupy the space. The assembly should be finished by Dec 2007.

When the support structure is ready for crystal/PMT loading, we will have over 5000 crystals and PMT's in hand. We estimate that by April 2008, we will have enough crystals/PMT's glued together and ready for loading to complete the staged EMCAL with ~5000 crystals. As they are loaded into the support structure, they will be tested to make sure they all work.

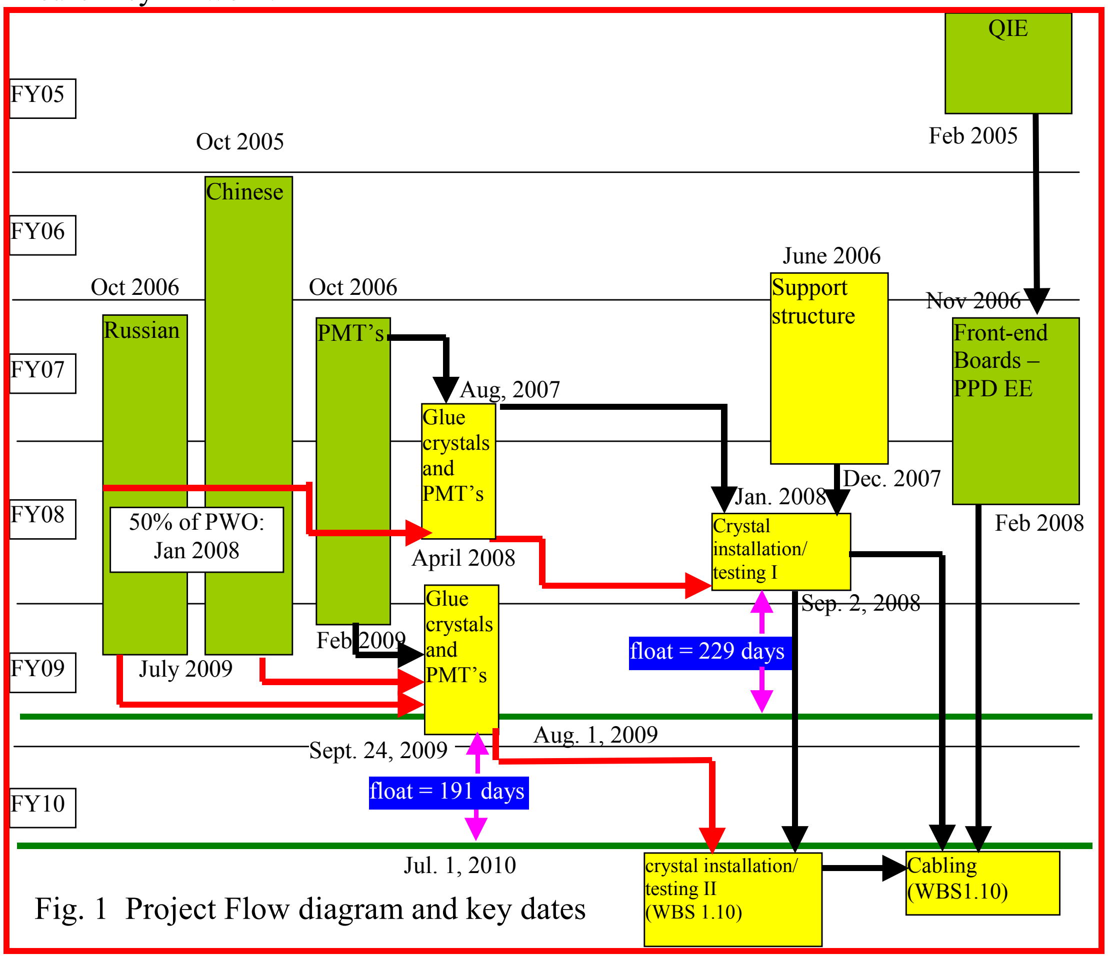


Figure 37: Project Flow diagram for EMCAL

If everything goes smoothly, we will load about 1000 crystals/month, and by August 2008, the loading rate is limited by the availability of new crystals and PMT's. Nevertheless, by May of 2009, we should have all the crystals in the support structure before the 2009 summer shutdown when the staged BTeV is put together.

However, the history of crystal calorimeter has its share of crystal production delays. We feel, however, it is very likely that at least half of the crystals will be installed by the summer 2009 since even if the production rate is half as much as projected, this will be accomplished.

Some of the risk factors and our mitigation strategies associated with crystal production delays are discussed near the end of this chapter.

When the FEB boards are fabricated, tested and ready to be installed (February 2008), we will load them in the subracks near the detector, and we will connect signal as well as HV cables to the PMT's, and do more comprehensive tests all the way to the FEB boards.

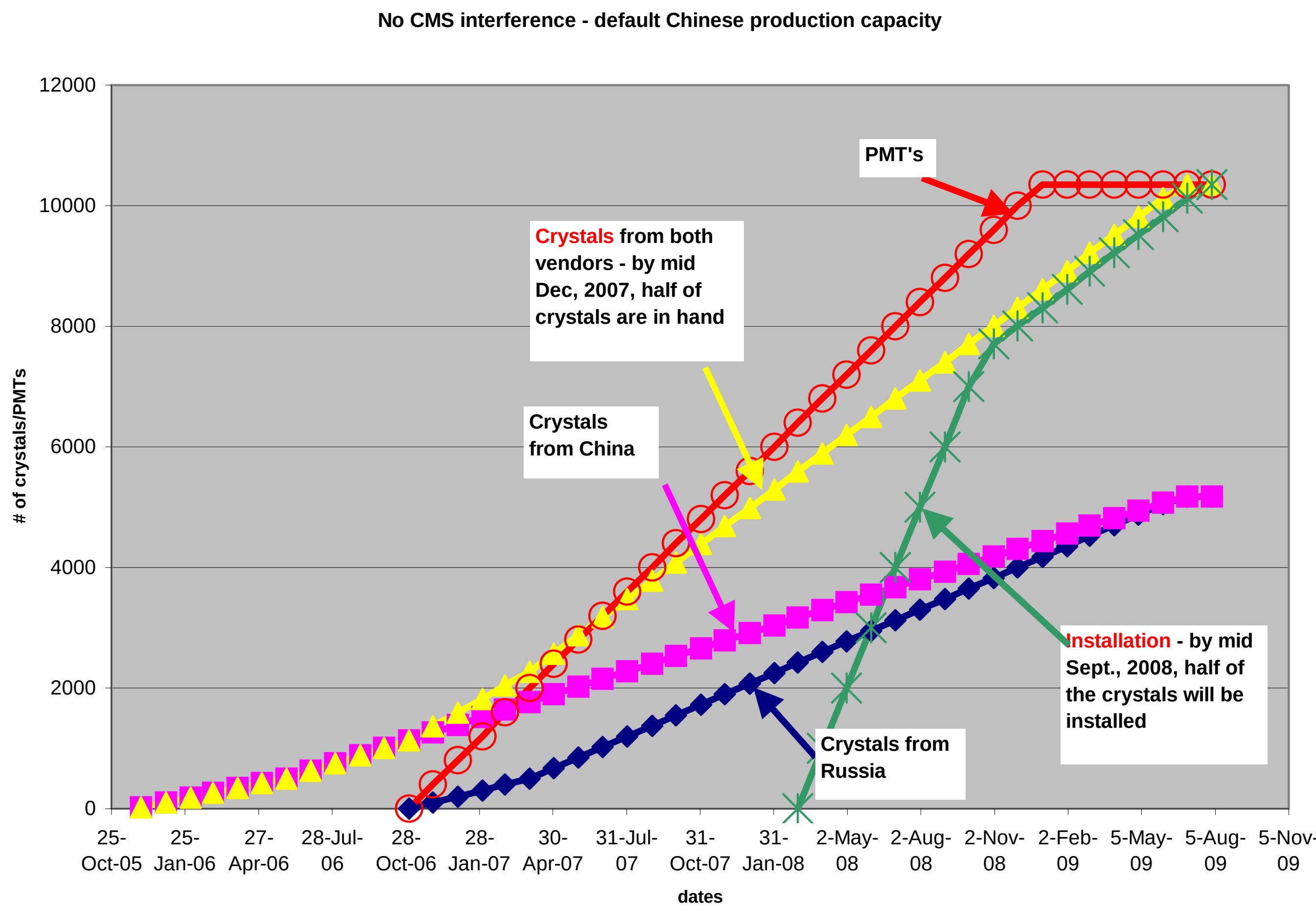


Figure 38: Schedule of crystal and PMT acquisition and installation

When a partial DAQ system is available in the fall 2008, we will connect FEB's to the DAQ to carry out whole-system tests.

7.4.2.3 Labor Profile

The labor profile is shown below. On the average, we will need about 10 FTE's to do the work. Considering that many of us are multitasking, we will need 15-20 "bodies" as the Lehman CD-1 reviewers pointed out. Concentration of work on EMCAL specific database work in FY06 will be spread over longer time scale.

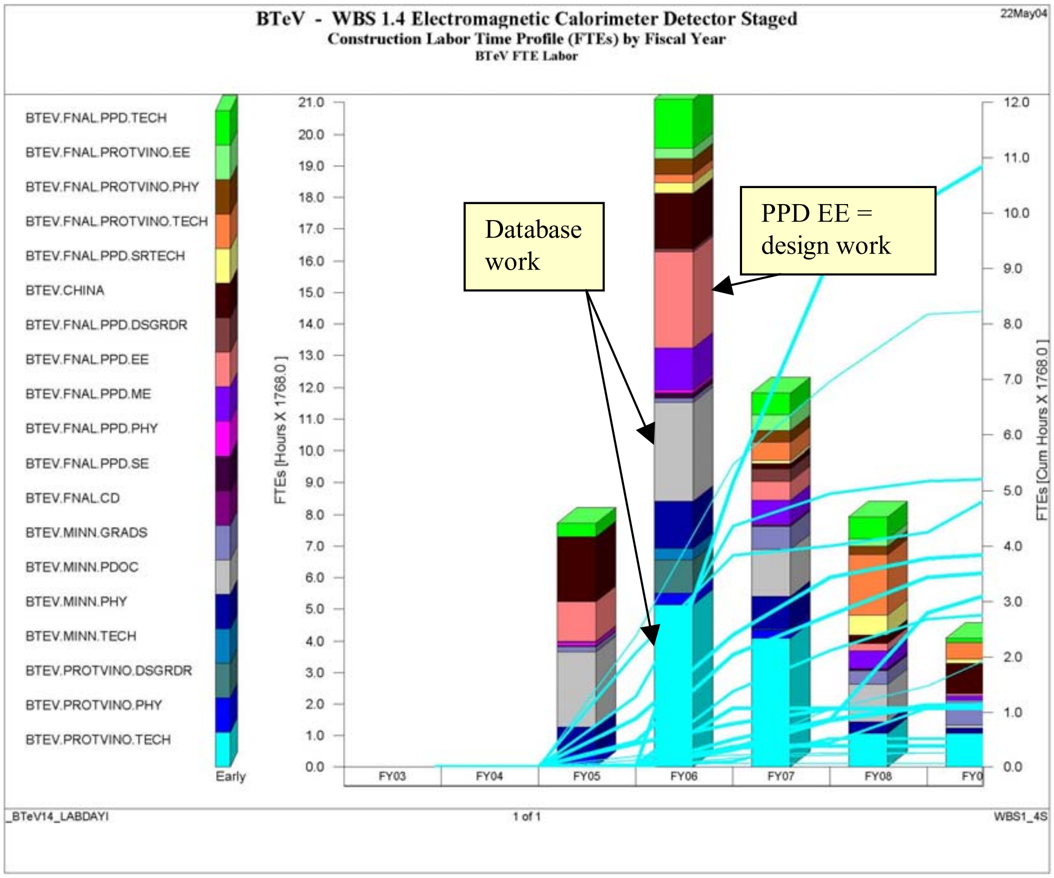


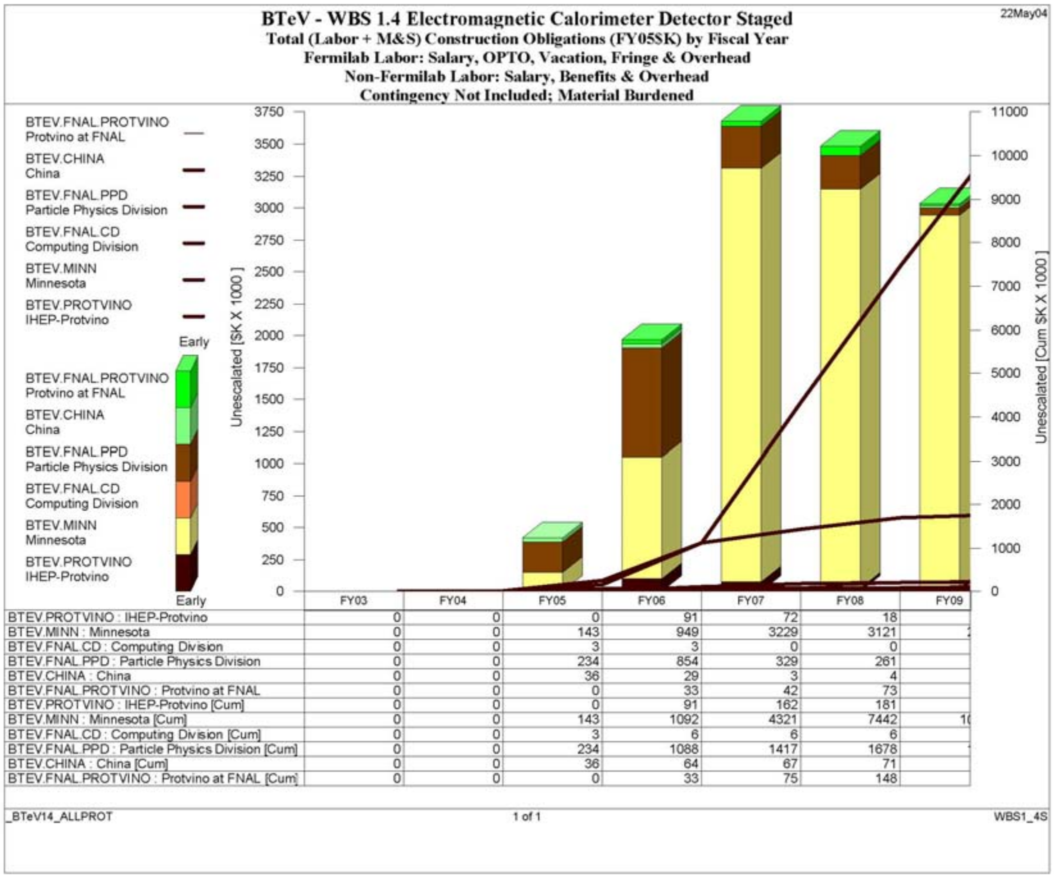
Fig. 2 Labor profile

Figure 39: Labor Profile

7.4.2.4 Cost Profile

The total base cost of EMCAL is \$12.5M and \$16.7M including contingencies, with average contingency rate of 33.6%. Only \$2M of the base is for labor and the rest (over \$10M) is for M&S because PWO crystals and PMT's are expensive. The cost profile by fiscal year is given below. This represents \$300k increase to speed up the Chinese crystal production by investing it to boost their production capacity (in the form of higher unit cost).

Figure 40: Cost Profile



	FY03	FY04	FY05	FY06	FY07	FY08	FY09
BTEV.PROTVINO : IHEP-Protvino	0	0	0	91	72	18	
BTEV.MINN : Minnesota	0	0	143	949	3229	3121	
BTEV.FNAL.CD : Computing Division	0	0	3	3	0	0	
BTEV.FNAL.PPD : Particle Physics Division	0	0	234	854	329	261	
BTEV.CHINA : China	0	0	36	29	3	4	
BTEV.FNAL.PROTVINO : Protvino at FNAL	0	0	0	33	42	73	
BTEV.PROTVINO : IHEP-Protvino [Cum]	0	0	0	91	162	181	
BTEV.MINN : Minnesota [Cum]	0	0	143	1092	4321	7442	[illegible]
BTEV.FNAL.CD : Computing Division [Cum]	0	0	3	6	6	6	
BTEV.FNAL.PPD : Particle Physics Division [Cum]	0	0	234	1088	1417	1678	[illegible]
BTEV.CHINA : China [Cum]	0	0	36	64	67	71	
BTEV.FNAL.PROTVINO : Protvino at FNAL [Cum]	0	0	0	33	75	148	

Fig. 3 Cost Profile

7.4.2.5 Critical path

a. As shown in Figure 37, the critical path is for a chain of events including crystals production and gluing of PMT's to the crystals. The stage 1 completion is planned on Sept, 2, 2008, 229 days in advance of so-called "need by" date of Aug. 2009.
b. The second half of the crystals will be ready for loading on Sept 24, 2009, 191 days ahead of the "need by" day, July 1, 2010.
c. If everything goes smoothly, we will have all the crystals in hand by the first shutdown (2009).

7.4.2.6 OBrowser views of Costs

Activity ID	Activity Name	Material($)	Labor($)	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Base FY05	Base FY06	Base FY07	Base FY08	Base FY09	Base FY05-09
1.4.1	Detector - PWO Crystals	6,093,310	181,832	6,275,142	40	30	78,253	324,556	826,825	2,099,536	2,945,972	6,275,142
1.4.2	Detectors - PMT's bases	2,149,969	141,332	2,291,301	28	24	2,525	156,814	1,066,442	1,049,384	16,136	2,291,301
1.4.3	EMCAL Electronics and Associated Infrastructure	1,510,739	639,067	2,149,806	30	30	298,390	361,663	1,481,975	7,778	0	2,149,806
1.4.4	Mech Air and Temperature ctrl Systems	402,561	600,452	1,003,013	20	24	0	545,421	189,001	227,879	40,712	1,003,013
1.4.5	Integration and Testing	114,542	460,324	574,866	26	32	3,241	510,042	52,983	8,600	0	574,866
1.4.6	EM Calorimeter Detector Subproject Management	67,975	191,024	258,999	38	25	33,739	59,818	57,399	84,130	23,913	258,999
1.4	**Subproject 1.4**	**10,339,095**	**2,214,031**	**12,553,126**	**35**	**28**	**416,148**	**1,958,313**	**3,674,626**	**3,477,306**	**3,026,733**	**12,553,126**

7.4.2.7 How Costs have Changed from CD-1 Review

By making activities run in parallel, we were able to spread the purchasing of crystals and PMT's over longer term and were able to delay spending of money to later years. For example, we should be able to start testing crystals earlier for each OpenPlan activity of purchase, which consists of multiple physical batches of crystal shipments. As soon as the first shipment arrives, the testing can start. The following graph shows how the cost profile for EMCAL changed since CD-1 review in April 2004.

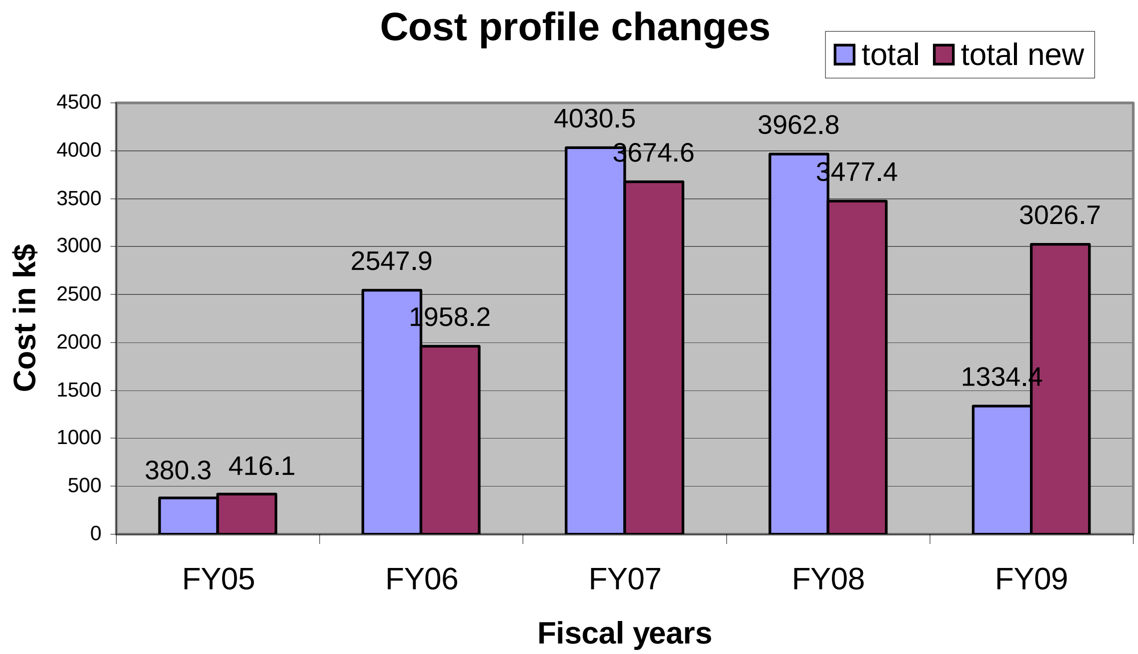


Fig. 5 Cost changes from CD-1

Figure 41: Cost changes to EMCAL since CD1 review

7.4.2.8 Installation

Before 2009 Shutdown

i. Load ~5000 crystals (PMT's attached) and test them for proper operation.

2009 shutdown

i. Move the support structure, with crystals, from the Assembly Hall to C0.

ii. Install light pulsers and front-end electronics (FEB) near the detector.

iii. Install optical fibers, signal cables and HV cables, and connect them to the light pulsers and front-end electronics (FEB) near the detector, and HV power supplies just outside the C0 Hall.

iv. Connect FEB's to DAQ.

2010 shutdown

i. Load crystals (PMT's attached) and test them.

ii. Install optical fibers, signal cables and HV cables, and connect them to the light pulsers and front-end electronics (FEB) near the detector, and HV power supplies just outside the C0 Hall.

d. Time & Effort

We project that it will take about 50 days of work in each of the two shutdown periods. The labor resources we need are

a. 200 man-days (mostly physicists) to load crystals in the Assembly Hall before the 2009 shutdown,

b. 270 man-days (physicists and technicians plus minimal engineers) during the shutdown, and

c. 275 man-days (physicists and technicians) for the 2010 shutdown.

In case the crystal loading before the shutdown is behind schedule and more needs to be done during the shutdown periods, we will use more crews for crystal loading and/or more than one shift per day to make sure they are done within the allotted time scale.

e. Possible interferences

Since major part of the EMCAL installation operation is the installation of crystals, which takes place between EMCAL and the muon toroids, we do not anticipate any interference with other detector groups.

There will be interference when the support structure is moved into the C0 Hall ((i) above) and when cables are laid out ((ii) above).

7.4.3 Response to all CD-1 recommendations

Explore ways to arrive at a schedule with comfortable float (>6 months) by working with BTeV Management and Installation & Integration group.

Staged installation of EMCAL is our answer to this recommendation. We now have a minimum of 191 business days (~ 9 months) of floats.

Add an Installation Engineer to the project.

More engineering is being added as a shared resource to the Project Office.

Add US collaborators

We are working on various possibilities.

7.4.4 Risk Table and Mitigation Strategies:

As the CMS experiences indicate, acquisition of crystals with only a few manufacturers can be risky. CMS narrowed the vendor field to one fairly early in their process, which may be one of the reasons that they are having trouble with the vendor. We are determined to keep at least two vendors competing for our orders.

Another risk regarding crystal acquisition is that CMS may decide to use SIC as well as Bogoroditsk for their crystal production. In this scenario, both manufacturers will be busy with CMS crystal productions until mid-2007. However, SIC will have 3 times the current production capacity (or 330 crystals/month) if this happens because CMS needs this capacity. Bogoroditsk currently have enough capacity to produce all 5000 crystals in 5 months. As the schedule diagram below shows, we will be able to finish our crystal production and installation in time.

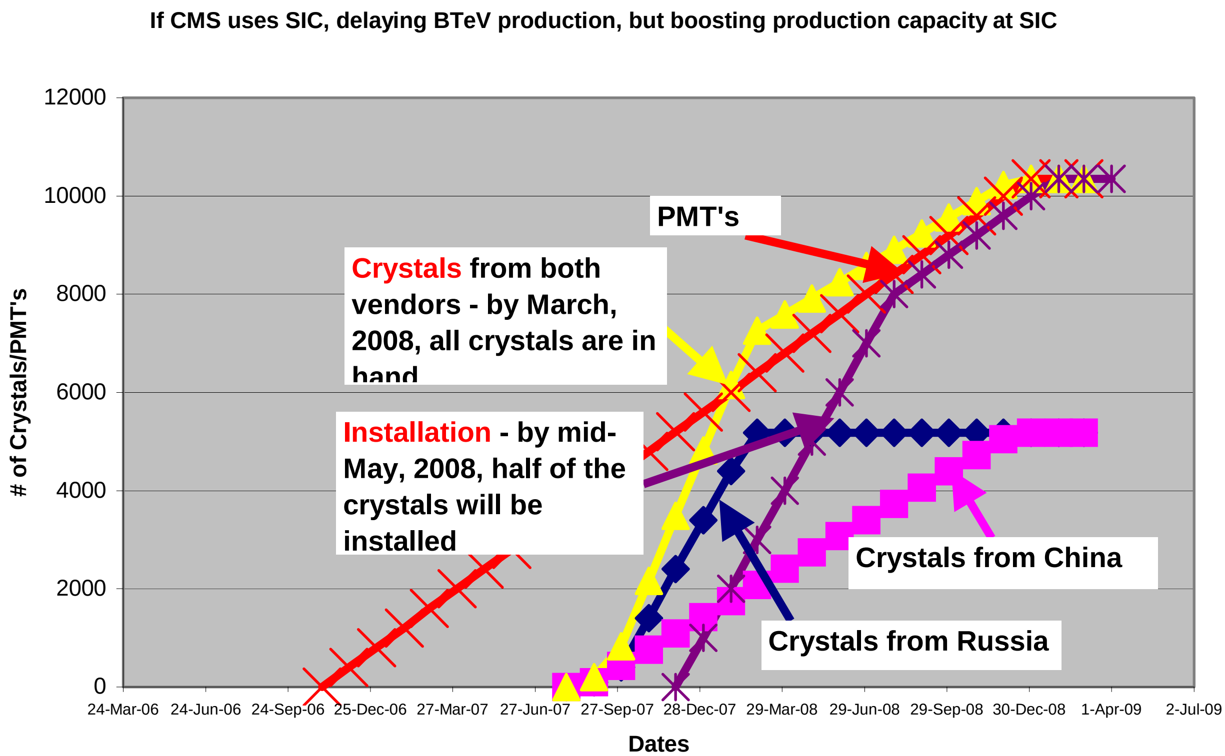


Fig. 6: alternative crystal production schedule in case vendors are busy with CMS crystal production until mid-2007.

Figure 42: Alternative crystal production schedule

7.5 Schedule for Muon Detector (WBS 1.5)

7.5.1 Introduction

7.5.1.1 Description

The Muon System provides both offline muon identification for BTeV and information for the experiment's trigger. The system is a toroidal magnet design with fine-grained tracking to provide a stand-alone di-muon trigger for the first level trigger. This design also allows for momentum confirmation in the offline identification which improves background rejection.

The Muon System is composed of three 5 m diameter tracking stations and a toroid assembly consisting of two roughly 1 meter thick iron toroids with 1.5 Tesla fields magnetized by a common set of coils. One station (station 1) of detectors is located between the two halves of the toroid assembly, the other two (stations 2 and 3) are in the well-shielded region downstream of the toroid iron. The basic building block of the detector is the "plank:" two layers of 16 stainless steel proportional tubes (32 in all) offset by half a tube diameter in a picket fence geometry. Each layer of tracking is covered by 8 overlapping pie shaped "octants." Each octant consists of 12 planks arranged perpendicular to the beam and to the radial line that bisects the octant. Planks near the beam are short, far from the beam are long. This helps distribute the occupancy of the proportional tubes. Each station consists of four layers of tracking: two *r* views as above and two "stereo" views that are tilted at ± 22.5 degrees in the detector plane to provide information on the azimuthal angle φ. There are 96 octants, 1152 planks, and 36,864 proportional tubes in the full muon system.

7.5.1.2 Staged Detector

For Stage 1 of BTeV, we will install the two downstream detector stations (stations 2 and 3). This allows for offline muon identification but does not allow for the level 1, stand-alone, di-muon trigger. Subsequent installation of station 1 between the two halves of the toriod assembly will provide the full functionality of the system.

7.5.2 Muon Project Flow and Cost

7.5.2.1 "Ready by" and "Need by" Dates"

The items to be delivered by WBS 1.5 are three stations of muon detectors, hanging and installation hardware, and associated support systems such as gas and HV systems.

Planks will be fabricated in assembly lines at three universities: Illinois, Puerto Rico-Mayaguez, and Vanderbilt. Octants will be assembled at Illinois and Vanderbilt. Each octant is a self-contained unit with only a small number of external connections. An extensive quality assurance program is planned at all stages from plank fabrication through octant assembly, including tension measurement of the central proportional tube wires and a full readout, gas system, and HV test of each octant when it is completed. This octant test will be performed at each assembly site and again at Fermilab upon arrival there.

The Need By and Ready By dates for the muon system are given in Table 16. As discussed above, the Ready By date for the first completed station (Station 2) is set by the availability of front-end cards. The Ready By date for the last station completed (Station 1) is set by plank production. The Need By dates are determined by the installation schedule. The floats shown are in working days. Currently the first two muon stations are to be installed during the 2009 shutdown. We may install stations in earlier shutdown periods if things are going very well.

A secondary set of Ready By and Need By dates is associated with the Gas System. The relevant information is summarized in Table 17. The purchase of parts and assembly of the Gas System is completely independent project from the rest of the muon system. It has a duration of 100 days and a float of 608 days. Because of its independence and relatively short duration compared to its float, we do not consider this project on our critical path.

Station	**Ready By**	**Need By**	**Float**
2	7/02/2007	8/21/2009	537 days
3	9/01/2007	8/21/2009	474 days
1	9/08/2008	8/01/2010	475 days

Table 16: Ready By, Need By, and Floats for the three Muon Stations. Stations 2 and 3 will be assembled and installed first. Station 1, which goes between the two halves of the toroid assembly, will be installed last.

Secondary	**Ready By**	**Need By**	**Float**
Gas Sys	3/05/2007	8/03/2009	608 days

Table 17: Ready By, Need By, and Floats for the Muon Gas System, which is a “secondary” set of Need By and Ready By dates.

7.5.2.2 Project Flow

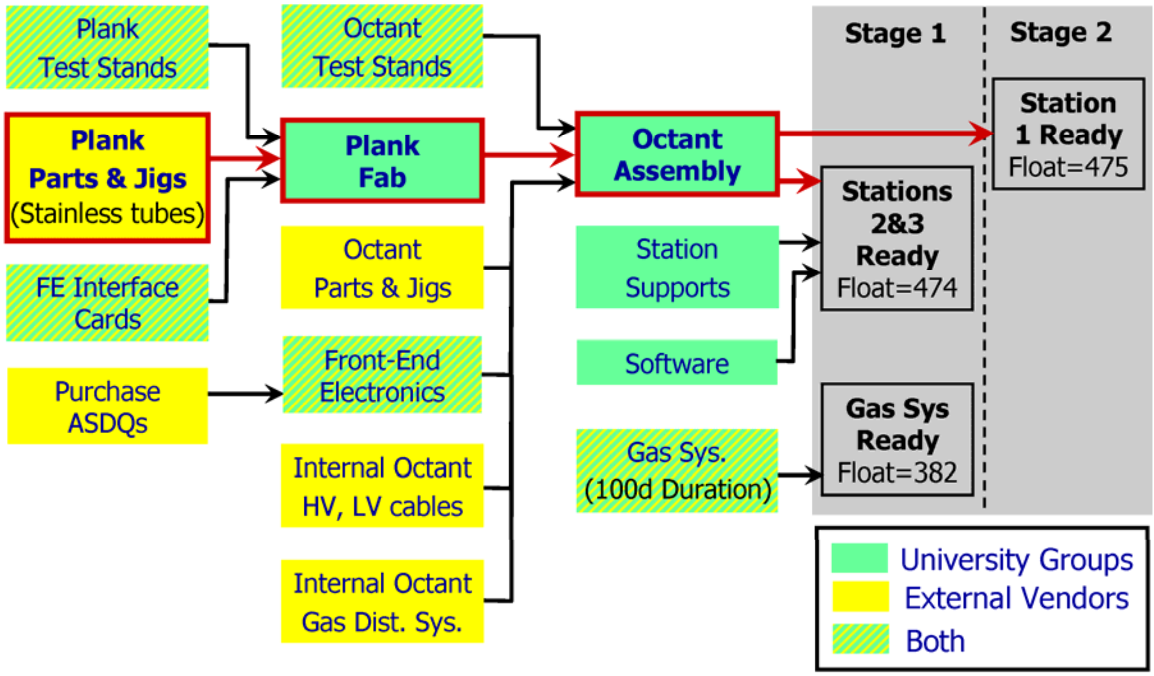


Figure 43: Project Flow Diagram for WBS 1.5

The project flow for this project is relatively simple (see Figure 43). The task that paces the entire schedule is plank fabrication. Each site will fabricate one plank per day. We will assemble 1479 total production planks, at this rate plank fabrication will take 27.5 calendar months to complete. Some plank parts will be made in the Vanderbilt machine shop, this process will take a roughly equivalent time. These long duration tasks are given priority in our scheduling process; we are starting them as early as possible. This is the beginning of FY06 when sufficient funds become available. Plank part production in the Vanderbilt shop can begin immediately, but plank fabrication must wait for our initial order of stainless steel tubes to arrive (we will order 50% in FY06, the remainder in FY07). The stainless tubes are a major cost item and have a long delivery time (4—6 months). Although we will need a small number of front-end electronics boards to test planks as they are produced, the great majority of front-end electronics boards are not needed until the planks are assembled into octants, and we take advantage of this in our production plan.

We estimate that it will take two days (wall clock time) to assemble the support structure for each octant, attach the twelve planks to it, and then install the front-end electronics, gas distribution system, and readout, HV, and LV cabling. Octants will be assembled in a vertical position using a hanging fixture, and completed octants will be stored in the same position on rolling carts (4—8 octants per cart) that will be used to transport the octants to Fermilab and to store them there before they are installed in C0. We plan to acquire the parts for the octant support structure early. As planks are produced, they will be attached to octants and stored on the rolling carts. Initially, front-end cards will not have been produced and HV/LV cabling and gas system parts will not have been acquired; these will be added later as they arrive. This determines when the first complete octants will be finished. However, once front-end cards become available, octant production can proceed rapidly and will quickly catch up to plank production. For most of the octants produced, it will be the availability of planks that determines their completion date.

7.5.2.3 Muon Labor Profile

The labor profile for the project is shown in Figure 44. The labor required in the university groups is consistent with the historical size of these groups. This includes the student labor required.

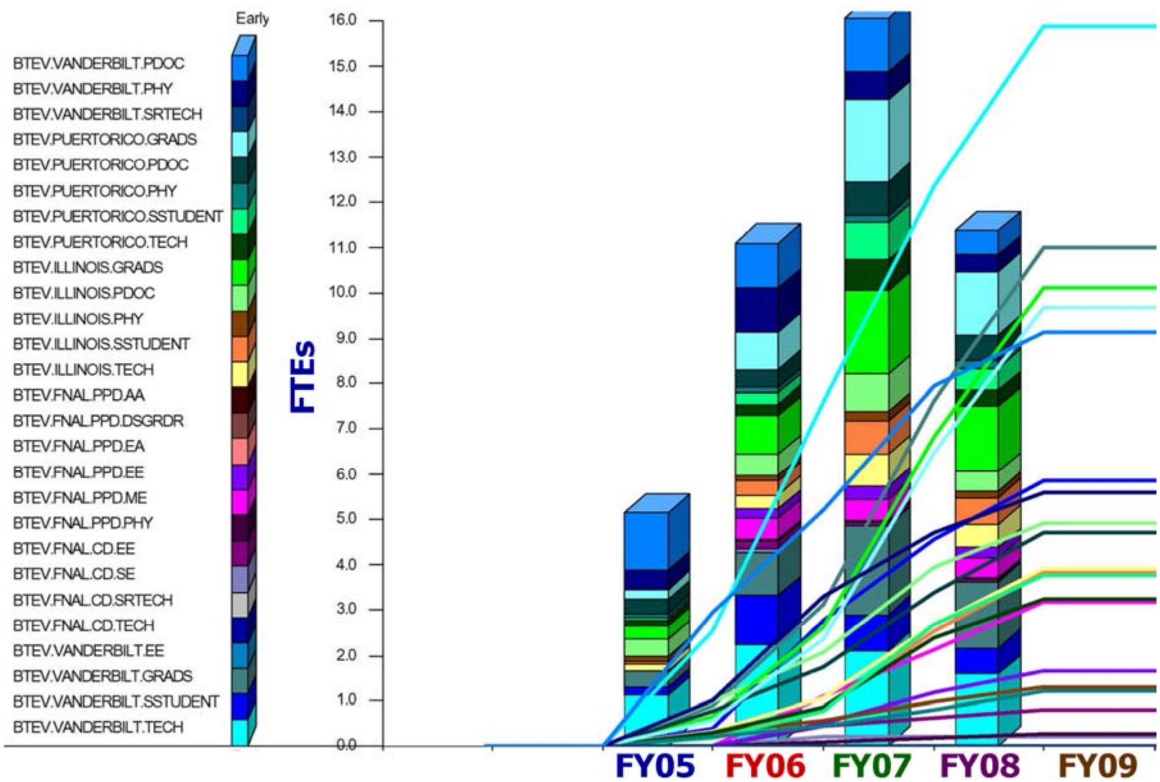


Figure 44: Labor profile for WBS 1.5.

7.5.2.4 Muon Cost Profile

The cost profile for the muon system construction project is shown in Figure 45. All costs are in FY05 dollars and reflect the obligation date. Contingency is not included. The costs broken down by sub-project are shown in Table 19. The large relative cost of the planks and electronics reflect their importance in the project. Our material contingency is influenced by objects such as the stainless steel tubes. Large recent changes in the price of steel led to a recommendation from a Temple review of a contingency of 75% on this object.

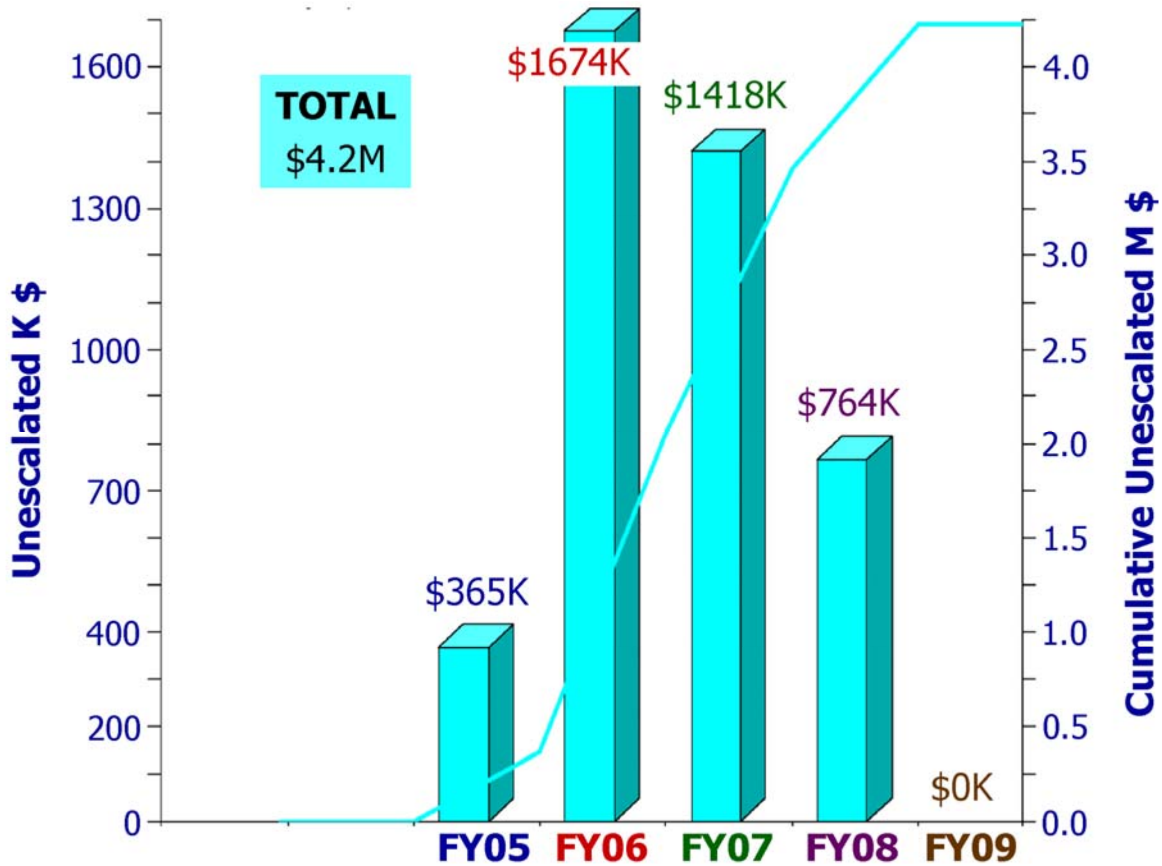


Figure 45: Cost Profile for WBS 1.5. All costs are in FY05 dollars, and do not include contingency.

7.5.2.5 Critical Path

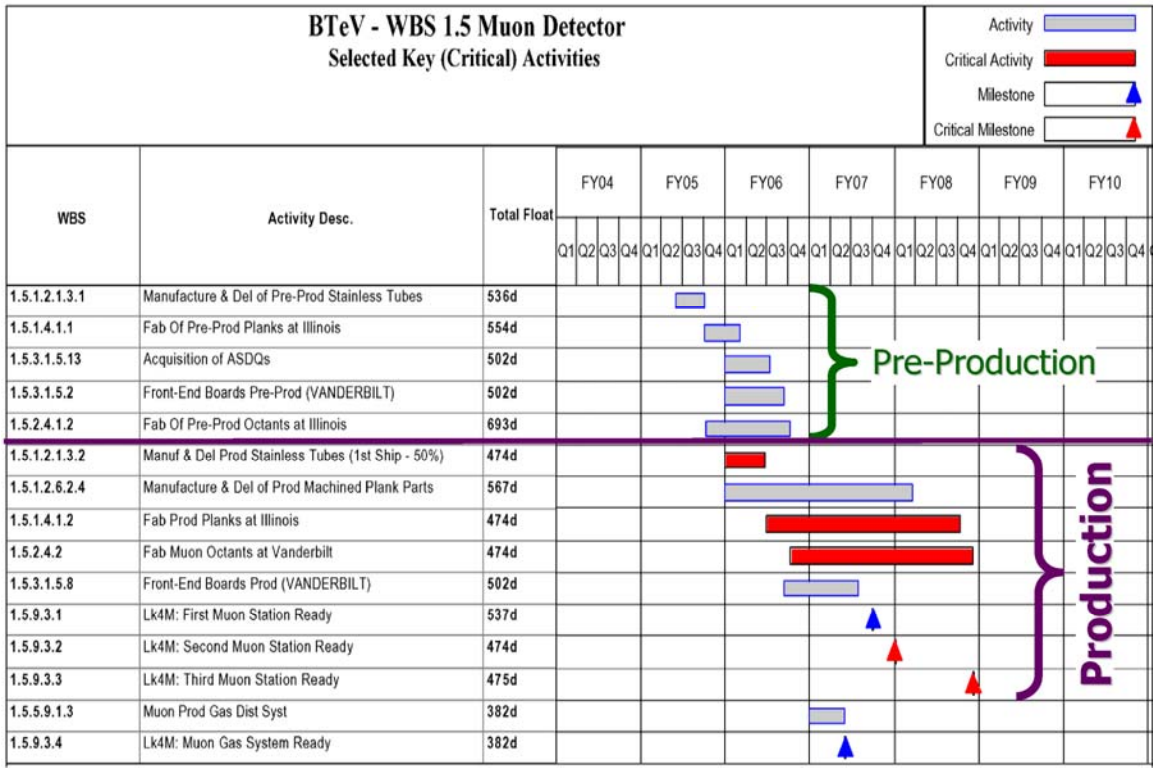


Figure 46: Critical path and near critical path items for WBS 1.5.

The critical path for the muon project (shown in Figure 46) is therefore (1) the initial purchase of stainless steel tubes at the beginning of FY06, (2) plank production, and (3) octant assembly.

To assure ourselves that our estimates of production times and to shakedown and debug our production methods, in FY05 we will begin a “pre-production” run of planks and octants. We will produce 8 pre-production octants. All three plank production sites will participate, and Illinois will assemble them into octants. We will not begin final plank production until we have evaluated the pre-production run. However, this run is scheduled to end three months before the arrival of the stainless steel tubes needed for the production run so it is not on the critical path. We will also wait to begin octant production until after we evaluated octant pre-production. However, it is the availability of front-end electronics that determines the start date of octant production and not this pre-production run.

In Table 18 we show how the float for each of the three muon stations changes under two delay scenarios. In case 1, we assume a three month (60 working days) delay in acquiring the stainless steel tubes. This delays the final two stations (3 and 1) by an equivalent amount (60 days). However, it has no effect on the delivery of the first completed station (Station 2) since that date is determined by the availability of front-end cards. This case is also equivalent to an increase of 3 months in the time it takes to fabricate the planks. In case 2, we show the effect of a delay of 3 months in delivery of the front-end cards. This could be caused by a delay in the acquisition of the ASDQs, for example. In this case, completion of the first station is delayed by 60 days, the second station is delayed by 32 days, and the final station is not delayed at all.

Station	Base Float	Case 1	Case 2
2	537 days	537 days	477 days
3	474 days	414 days	442 days
1	475 days	415 days	475 days

Table 18: Changes in float for each of the three muon stations under two delay scenarios described in the text.

7.5.2.6 OBrowser View of Cost Profile

Activity ID	Activity Name	Base Cost ($)	Material Contingency(%)	Labor Contingency(%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.5.1	Muon Detector Planks	1,498,016	51	35	224,133	883,521	928,011	182,281	0	2,217,946
1.5.2	Muon Detector Stations	328,787	40	35	62,038	221,776	133,093	40,076	0	456,982
1.5.3	Muon Detector Electronics	1,367,703	41	18	40,118	891,297	341,271	611,194	0	1,883,880
1.5.4	Muon Detector Test Stands	156,726	45	50	65,448	42,949	119,421	0	0	227,818
1.5.5	Muon Detector Gas System	118,953	50	0	0	106,050	63,354	0	0	169,404
1.5.6	Muon Detector Software	0	0	0	0	0	0	0	0	0
1.5.8	Muon Detector Subproj Mgmt	741,057	24	25	128,917	266,668	265,961	263,603	0	925,150
1.5	Subproject 1.5	4,211,242	45	27	520,654	2,412,260	1,851,111	1,097,154	0	5,881,179

Table 19: Project costs broken down by sub-project and fiscal year.

7.5.2.7 Changes in Costs from CD-1 Lehman Review

The majority of the difference in total cost is the addition of a full time technician to handle quality assurance and oversight for plank and octant production. This addition was the result of a CD-1 review recommendation (see section 7.5.3).

We also have performed some schedule optimization since the CD-1 review. Most of the costs in FY09/10 was engineering and this labor has been moved into FY06, 07, and 08. We also worked hard to minimize costs in FY05, pushing about $140K in costs into FY06 (FY05 costs did not go down by that amount because of the addition of the technician.) We also shifted some FY07 costs into FY06 to speed up production of the front-end cards. We also moved the purchase of HV supplies from FY07 to FY08.

	FY05	FY06	FY07	FY08	FY09/10	Total
CD-1	454	1307	1600	374	74	3809
Now	365	1674	1418	764	0	4221
Difference	-89	367	-182	390	-74	412

Table 20: Differences in cost profile between CD-1 and current schedule

7.5.2.8 Installation

It will take 10-15 working days (wall clock time) to install the first two muon stations and three working days to connect services and test/debug them. The final station, which is between the two halves of the toroid assembly and will be a little harder to install, requires 5-10 working days to install and two days in connect and test.

The main other installation project is the installation of the gas system. We assume that the gas line from the gas house to the collision hall will be installed by the time we arrive. Control lines, solenoids, and distribution lines to each octants must be installed, and the installation needs to be check out and tested. We estimate all of this will take 5-10 working days.

7.5.3 CD-1 Recommendations

The primary recommendation from the CD-1 review was that we hire a full-time quality assurance engineer for the duration of the project. After discussion this with project management, it was decided that additional effort will be added to the project office to handle QA issues for all of BTeV. The muon project will hire a full-time technician to handle QA and project oversight. We have added the cost of this technician to our WBS.

The other recommendation was that we pursue forward funding. We have proposed \$1M in forward funding to Vanderbilt and are in discussions with the Dean of Arts & Science, the Vice-Provost for Research, and the Provost regarding this proposal.

7.6 Schedule for Forward Straw Tracker (WBS 1.6)

7.6.1 Introduction

7.6.1.1 Description

The Forward Tracking Straw Detector is composed of seven stations of Straw drift chambers. The stations vary in size from 55 cm x 55 cm (Station 1, closest to the beam interaction region), to 3.8 m x 3.8 m (Station 7, which is 7.5 m from the interaction region). These detectors cover a 300 mr solid angle.

Each Station is comprised of three views, X, U, and V, oriented 90 and $\pm$11.2 degrees respectively from the horizontal. A view is made up of 3 close-packed planes of 4 mm diameter straws. The three planes provide a redundancy measurement as well as resolving the left-right ambiguity of the particle track. The position of a particle track is measured in an indivual straw detector by the detection of the arrival time of the charge cluster closest to the central anode wire.

In total there are approximately 29000 individual straws in the Forward Tracking Straw detector. Furthermore, since each anode wire is split into 2 individual halves (to lower the occupancy level) and read-out from both sides of the straw, the number of electonics channels is approximately 58000.

7.6.1.2 Staging

Since the Forward Tracking Straw Detector naturally divides into the seven independent stations, it is easy to consider staging the detector. It would facilitate the second installation stage if the first staged detectors could remain in place during the second installation stage Since a full installation of the stations of the Forward Tracking Straw Detector would follow in the order, 1, 2, 3, 6, 5, 4, the stage 1 installation of the Forward Tracking Detector would include stations 1, 2, 5, 6, and 7 (Station 7 is installed independently of the first six stations).

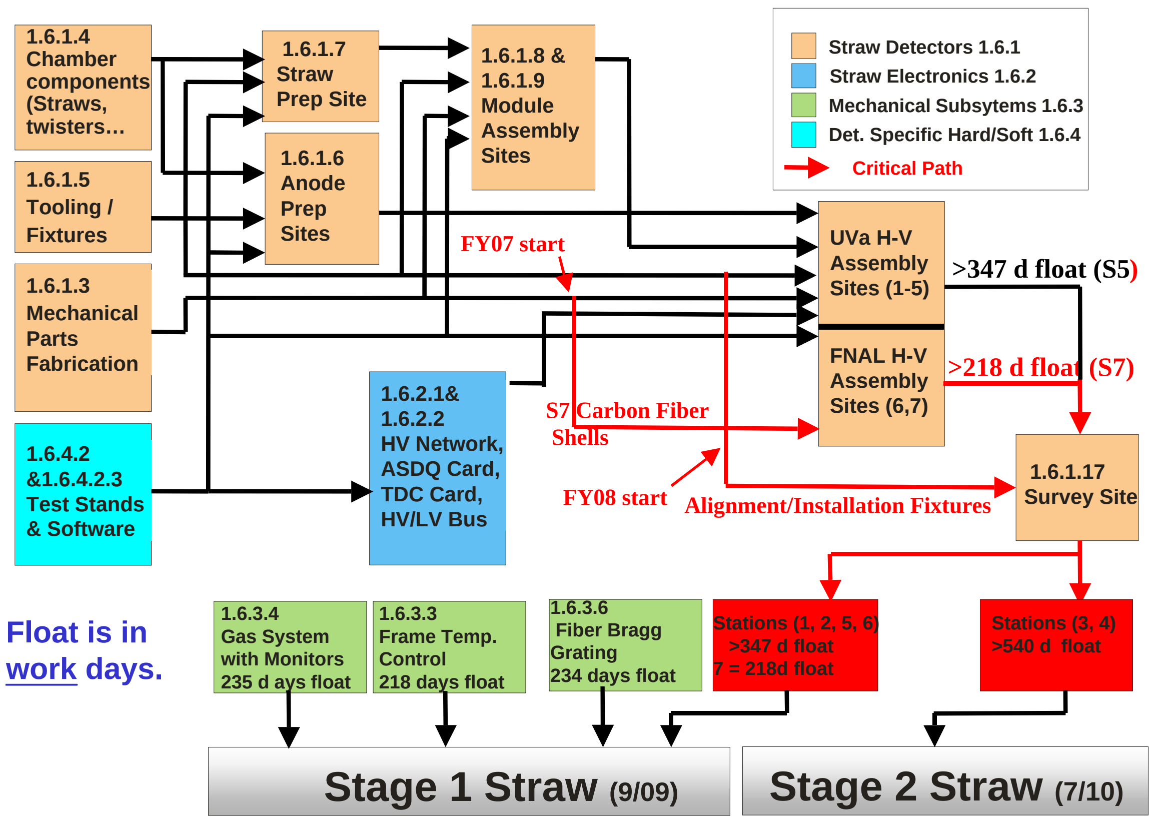
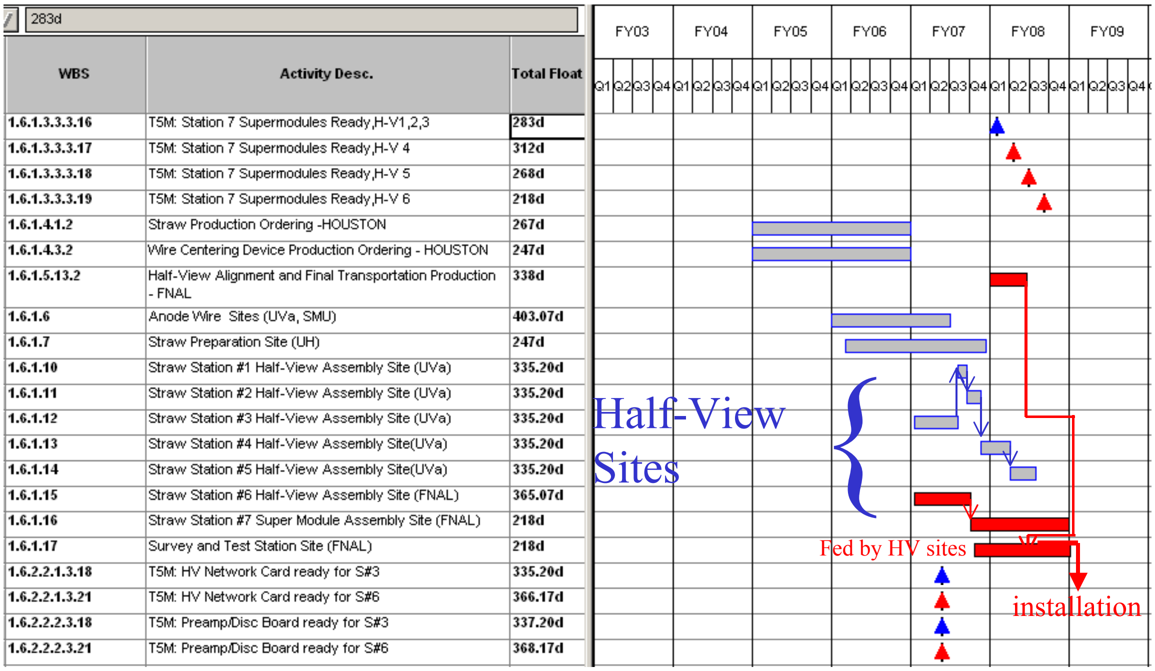


Figure 47: Flow Diagram of the Forward Tracking Straw Detector. Floats shown are the current (not Lehman CD1) values

7.6.2 Project Flow and Cost

A block diagram of the Project flow is shown in Figure 47. The construction of the Forward Tracking Straw Detector takes place at the sites of the collaborators. This work includes the Anode Wire Sites (at UVa and SMU), which produce the split anode wires, and the Straw Prep Site (UH) which receives the straws and twisters, does the QC, and assembles the items into a straw which is sized for a particular station. This work begins as soon as possible in the project timeline, as the remaining Straw production depends upon the output from these sites. The assembly of the straws and anodes into the working Stations take place at FNAL and UVa "Half-View" (H-V) Assembly sites . FNAL assembles Stations 6 and7, and UVa Stations 1-5. In addition to the physical detectors, the Front-End Electronics construction (WBS # 1.6.2.1 &1.6.2.2 as seen in Figure 47) takes place at UVa (HV Network Card, ASDQ Card), SMU (HV and LV bus cards) and FNAL (TDC cards). Since it would be advantageous to have these cards available to test and QC the Stations as they are being assembled, the final QC of the stations have been made contingent upon having these Front End cards. This flow is depicted in Figure 34. The red lines indicate "critical" paths which determine the maximum amount of "float" of the project.



283d

WBS	Activity Desc.	Total Float
1.6.1.3.3.3.16	T5M: Station 7 Supermodules Ready,H-V1,2,3	283d
1.6.1.3.3.3.17	T5M: Station 7 Supermodules Ready,H-V 4	312d
1.6.1.3.3.3.18	T5M: Station 7 Supermodules Ready,H-V 5	268d
1.6.1.3.3.3.19	T5M: Station 7 Supermodules Ready,H-V 6	218d
1.6.1.4.1.2	Straw Production Ordering -HOUSTON	267d
1.6.1.4.3.2	Wire Centering Device Production Ordering - HOUSTON	247d
1.6.1.5.13.2	Half-View Alignment and Final Transportation Production - FNAL	338d
1.6.1.6	Anode Wire Sites (UVa, SMU)	403.07d
1.6.1.7	Straw Preparation Site (UH)	247d
1.6.1.10	Straw Station #1 Half-View Assembly Site (UVa)	335.20d
1.6.1.11	Straw Station #2 Half-View Assembly Site (UVa)	335.20d
1.6.1.12	Straw Station #3 Half-View Assembly Site (UVa)	335.20d
1.6.1.13	Straw Station #4 Half-View Assembly Site(UVa)	335.20d
1.6.1.14	Straw Station #5 Half-View Assembly Site(UVa)	335.20d
1.6.1.15	Straw Station #6 Half-View Assembly Site (FNAL)	365.07d
1.6.1.16	Straw Station #7 Super Module Assembly Site (FNAL)	218d
1.6.1.17	Survey and Test Station Site (FNAL)	218d
1.6.2.2.1.3.18	T5M: HV Network Card ready for S#3	335.20d
1.6.2.2.1.3.21	T5M: HV Network Card ready for S#6	366.17d
1.6.2.2.2.3.18	T5M: Preamp/Disc Board ready for S#3	337.20d
1.6.2.2.2.3.21	T5M: Preamp/Disc Board ready for S#6	368.17d

Figure 48: Gantt Chart Of WBS 1.6. Red color signifies items which are either on or near the critical path.

At the time of the Lehman CD1 (April 2004) review, the Front End Cards were responsible for the critical path of the entire Forward Tracking Straw Detector, giving rise to a 46 day float. This float was calculated with respect to “need-by” dates of May 1, 2009 (Stations 1-3) and June 1, 2009 (Stations 4-7). There are other parallel paths for items in the 1.6 Straw subproject (gas systems, low and high voltage power supplies, etc as shown in Figure 51 which feed into the Straw Installation at C0, but they do not feed directly into the production of the actual stations. The minimum float (for the Lehman CD1 review) was 19 days for the HV and LV power supplies, but this was referenced to a “need-by” date of January 2008, the date we intend to make the purchase of HV and LV for the entire BTeV detector, and thus is not actually critical. The actual Lehman CD1 floats for the individual Stations (and not simply the 46 days of float of the last assembled station) is shown in the Table.

In order to understand how to stage the detector so that we could create an acceptable amount of float (with acceptable being defined later), it was necessary to make a detailed study on the predecessor-successor relationships which set the critical path shown for the Lehman CD1 Review. Under close scrutiny, it was determined that the Front-End Card and the Half-View Production Site relationship was faulty. Due to the constraints of the cost profile which was (and is) in force for the Lehman CD1 review, both the final production of the Front End Cards and the Start of the Half-View Assembly Sites was held off to the start of FY2007. The faulty relationship was that the initial start of the Half View Sites was held off until the arrival of the first 1/3 of the Front End Cards. Under actual production, this would simply not be necessary. As long as the cards would be available before the end of the production of the Half-Views of a particular station, it would be possible to finish the confirmation of the detector meeting specifications. Also during construction, an anode tension measurement is made with the anode under HV, so the integrity of the construction process is already assured. The relaxing of the original tight constraint led to the recovery of ~100 days of float (for a total of ~146 days) for the last detector off the "assembly" line.

Another means to increase the subproject float was actually discussed at the breakout session of the Lehman CD1 review. The original production scheme assumed a single shift of two assembly lines at the Half-View Sites (except for Station 7 which already had 3 assembly lines). It was mentioned that it would be easily possible to increase the number of assembly lines from two to three, which would shorten the production time to 2/3 of the original length (~396 days) . This change has been made to the schedule, and has added another ~130 days of float . At this point the total number of days of float has been increased to 270 days of float for the UVa Site (stations 1-5) and ~200 days for the FNAL site (Stations 6&7).

The target dates for the first stage of installation have been moved back to late September 2009 (~80 more days of float), reflecting better the anticipated shutdown schedule, and the target date for the second stage July 1, 2010. With these new dates, the total amounts of float for the first staged detectors are shown in the fourth column of Table 22. In Column 3 of the same table, the "unstaged" detector float is shown (the July 2010 date was replaced with the September 2009 date). The reason for Station 7 staying at "only" 212 days is that there is a funding restraint on producing the carbon fiber reinforced Supermodule shells which accounts for the ~100 d loss of float time. This is shown in Figure 34 as a critical path (red line).This time could be made up by increasing the labor force available for the carbon fiber shell production (or moving its production date ~ 3 months earlier). It should also be noted that Station 7 is made up of supermodules (14 per view) that install one-by-one (in the order U, V, X). This is why the float in station 7 is shown as a function of view, unlike the other stations which install all 3 views simultaneously).

More tests were made to check the robustness of this schedule. In two cases, critical components were artificially delayed amounts which are comparable to deliverly schedules from actual quotations, and in the third the starting date of the project was delayed six months. In all cases, the delays barely affected the floats (as can be seen in Columns 5-7). The reason for the robustness is due (somewhat perversely) by the effort to meet the difficult cost profile. The only way to meet the profile was to delay starts onto the beginning of Fiscal Year boundaries. This produced significant time"gaps" between the production time and the need-by-dates (often in the next fiscal year). Thus delays in production schedules or project start dates take advantage of these unintended schedule contingencies.

1	2	3	4	5	6	7
Station #	Lehman CD1 float	Current non-staged float	Current staged float	Straw Production Extended by 60 days	Twister Production extended by 75 days	Project Start delayed 6 months
1	266 d	373 d	nc	nc	nc	nc
2	226 d	366 d	nc	nc	nc	nc
3	396 d	364 d	549 d	nc	nc	nc
4	281 d	357 d	542 d	nc	nc	nc
5	46 d	347 d	nc	nc	nc	nc
6	344 d	335 d	nc	nc	nc	nc
7 U	124 d	352 d	nc	312 d	nc	nc
7 V	124 d	289 d	nc	259 d	nc	nc
7 X	124 d	218 d	nc	207 d	nc	nc

Table 22: Float for Subproject 1.6 under various scenarios. The station production order for the Lehman CD1 Review was Stations (3, 4, 1, 2, 5) (UVa), and Stations (6, 7) (FNAL). For the other columns, the order of station production for UVa was changed to Stations (3, 1, 2, 4, 5) (UVa). All "days" are work days.

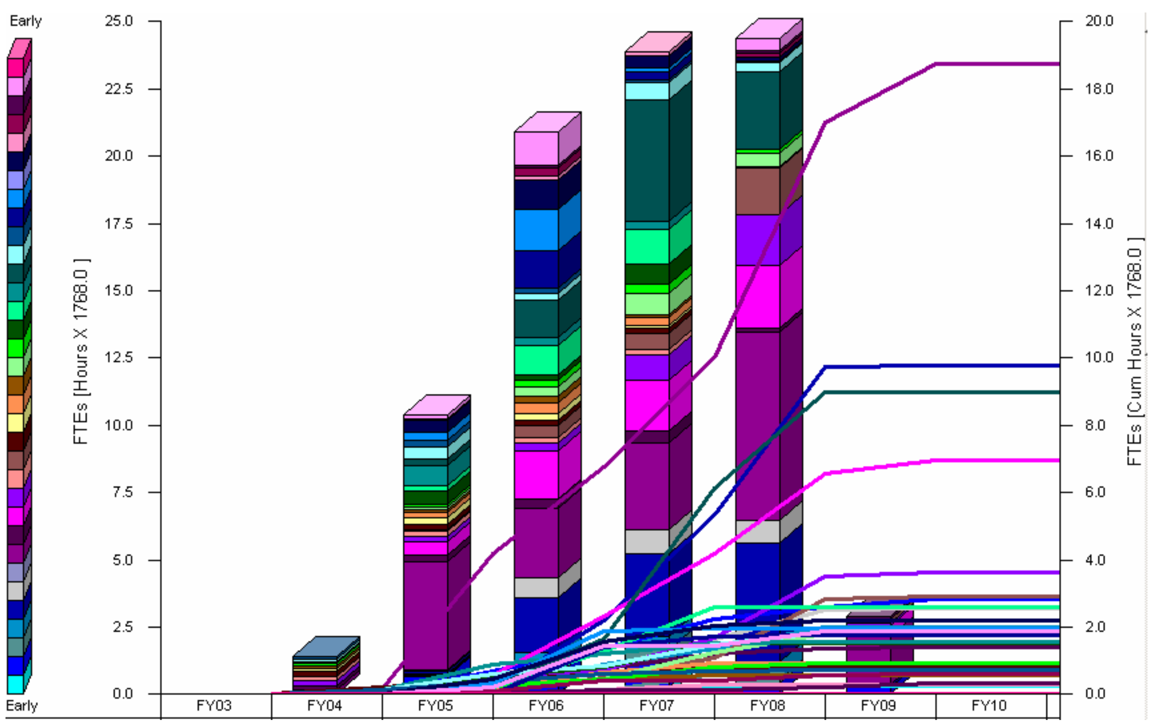


Figure 49: Labor Profile (FTE) vs FY

Figure 49 gives the labor profile (in FTE's) vs Fiscal Year for the current state of the subproject. It is somewhat more intensive in use of labor due to the addition of more assembly lines than the Lehman CD1 labor profile.

The cost profiles for the current project are shown in Figure 50 (without contingency) and Table 23 (with contingency).

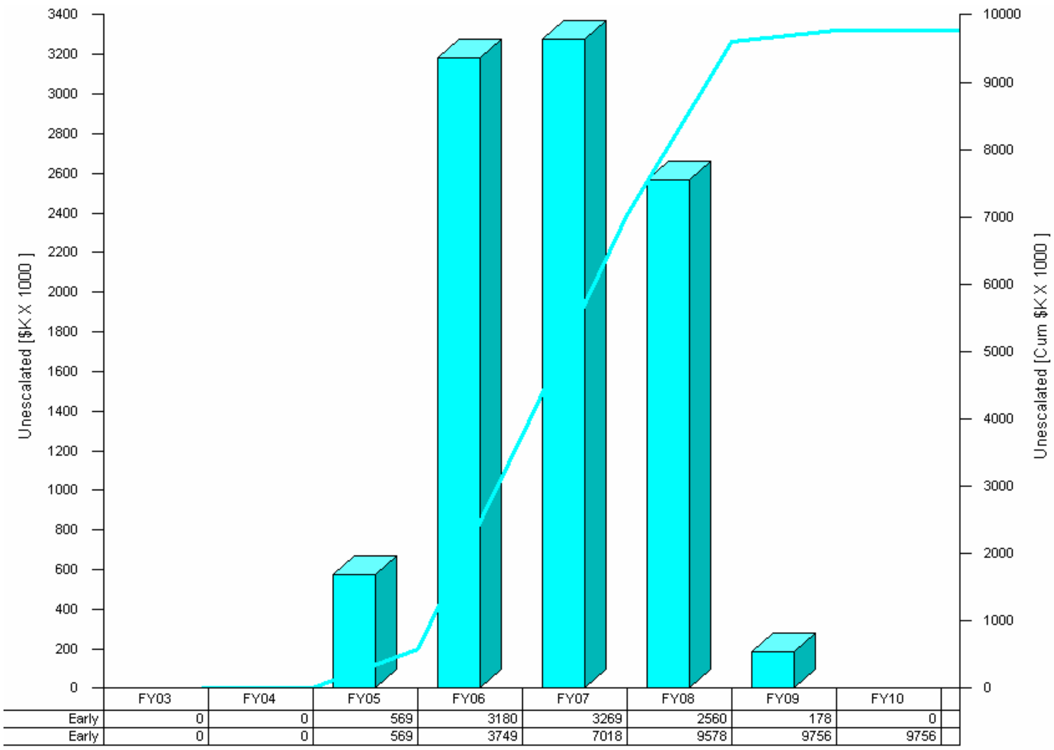


Figure 50: Cost (without contingency) vs FY.

Activity ID	Activity Name	Base Cost($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.6.1	Straw Chambers	6,076,045	23	29	198,401	2,702,277	2,618,657	2,075,863	53,672	7,648,869
1.6.2	Straw Detector Electronics	2,110,313	29	43	297,592	880,851	1,202,642	434,023	0	2,815,108
1.6.3	Mechanical Gas Calibration & Other Support Systems (FNAL SMU)	740,788	30	37	40,769	204,225	175,834	553,044	18,213	992,084
1.6.4	Integration & Testing (all)	271,383	31	71	130,235	101,553	65,853	41,698	31,739	371,078
1.6.5	Forward Tracker Straw Detector Subproject Management	560,945	30	30	150,030	152,421	150,627	150,627	125,523	729,228
1.6	**Subproject 1.6**	9,759,473	26	32	817,027	4,041,326	4,213,614	3,255,255	229,146	12,556,368

Table 23: Total Cost vs FY

Cost differences between Lehman CD1 review and Current WBS is +$285k. The majority of this cost differential comes from 1.6.1 (the "Straw Chambers") where we have added +$100k for an updated quote for the baseline Straws (carbon loaded kapton), and $180k for more of the Straw Station installation fixtures. This latter change (from 2 fixtures to 6) was to allow us to stage all the Stations before the 2009 shutdown period, in order to reduce the duration needed to install the detector. Staging of a single station in Lab 3(which involves mounting all six halfviews onto the fixture, then surveying each halfview by means on a CMM) takes a week of effort. The staged Station then waits the time for its installation into the beamline at C0. The previous method involved staging one station while the other was being installed at C0, which cost us one week of "deadtime" between stations.

The installation plan for the Forward Tracking Straw detector is captured in BTeV document #1040. Briefly the current plan is to minimize installation durations during the shutdown periods (particularly the 2009 shutdown). This is done by installing and checking all power supplies, cables, gas lines, cooling lines and other supporting hardware and software in the collision hall before the 2009 shutdown (during the 2008 and other access periods). In addition the actual Straw detectors and front-end electronics will already have been tested and debugged before arrival at C0. The intent is to keep the installation, survey, and checkout time per station on the order of ~2 days.

7.6.3 Response to CD-1 recommendations.

1. Select the straw material, straw diameter, and wire diameter within this year. Clear work plan should be provided

   We agree and will execute the following plan:
   - We will acquire new Copperized Kapton Straws and subject them to radiation tests
   - We will test 30 μm Anode wire
   - Currently use 25 μm wire
   - 30 μm is 50% stronger, but Voltage will be higher/
   - Will setup a work plan.

2. Put Additional Effort into aging test

   We agree and will do the following:

   - UH and UVa will test new straw materials (and anodes)
   - We will make setup with gas system similar to production system
   - UH, UVa, and SMU have proposal to undertake Rad Damage test at IU cyclotron

3. Produce more prototypes (preferentially in all production sites) and test. They should be built with production components and tooling as much as possible
    - We agree. This recommendation is consistent with our Station 3 HV prototype effort
    - All sites will produce consistent with their eventual production jobs
    - UH, SMU, UVa Rad Damage test at IU cyclotron will also produce a prototype detector.

4. Move up production schedule by ~6 months
    - Lehman CD1 float was 46 days (~2 calendar months).
    - By small rearrangement of dependencies between different activities, and production scheme, float can be made to be >200 days (10 calendar months), with relatively small impact on Cost profile.
    - Is this "good" enough? Any more would take a bit more effort with more impact on early years.

5. Strengthen management with a project engineer
    - Actually we do have project engineer(s) in management section of WBS
    - 0.5 FTE ME for project duration
    - 0.25 FTE EE for project duration
    - We will propose to also add
        - Production and QA engineer
        - This may be a split of the 0.5 FTE ME into 2 people @0.25 FTE
        - Site (L4) Managers (= engineers?) for external sites
        - Propose ~10% FTE for duration of work at site
        - Make this more obvious on my Org Chart!

7.7 Schedule for the Forward Microstrip Tracker (WBS 1.7)

7.7.1 Introduction

7.7.1.1 Description

The Micro-Strip project was found by the CD-1 Review in very good shape. The scope was evaluated "well defined and understood", the cost estimate "credible and provided with adequate contingency" and the schedule "credible, with Critical-Path identified and allowing for 6 month float". For this reason, we decided to keep the same schedule and the same funding profile. In the new scenario of staging, since the installation milestones have been changed, we suddenly gain an additional 3 month float on the most critical activities and can improve in general our schedule. Now, the resulting float is 186 days, i.e. about 9 calendar months.

Since the end of the CD-1 Review, a very important fact happened, which can further impact to several extents our schedule. We have approved by INFN and will be funded for the construction of the Micro-Strip system with a profile which should remove from our schedule any residual funding-limitation. The condition INFN is asking for to begin to fund us is that the BTeV construction be approved by DOE too. In this scenario, we can increase our float by other 3 months, for a total of 1 year about, if DOE approval would come by the end of this year, 2004.

7.7.1.2 Staging

All stations of the Forward Microstrip Tracker are likely to be ready before the first installation period. However, to ease the installation burden, we currently plan to install four stations, station 1, 2, 5 and 6 in the first period starting in August of 2009. The final three stations, 3,4, and 7, will be installed in the second period in July of 2010.

7.7.2 Project Flow and Cost

In Figure 51 a pictorial sketch of the Project Flow is given.

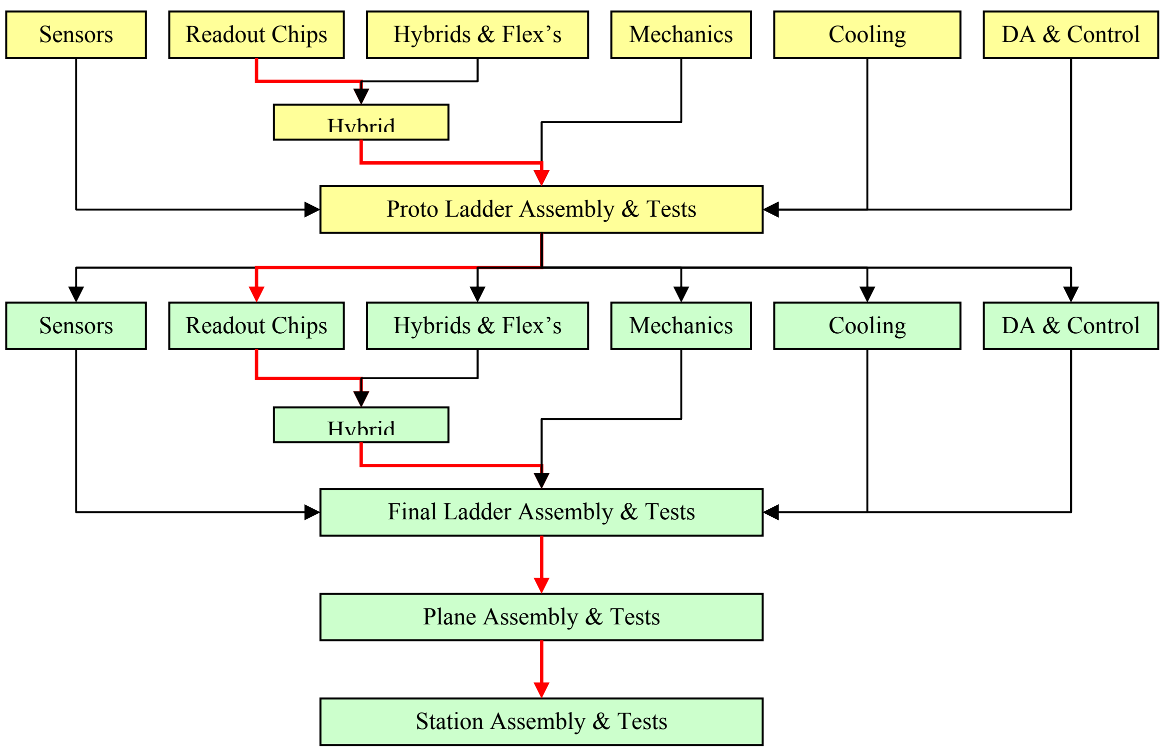


Figure 51: Sketch of the Project Flow

The critical path is driven by the sequence of activities necessary to prepare the readout chips, to assemble them on the hybrid circuits and, then, to assemble the detector ladders.

This sequence is repeated two times, one in the prototyping phase to build the prototype ladder, the other in the production phase to build the final ladders.
The detailed output of the standard Open Plan critical path analysis is reported in Figure 52. The smallest float is 186 days, i.e. more than 9 calendar months.

BTeV - WBS 1.7 Forward Tracker Strip Detector
Barchart for Critical Path Analysis
Sorted by Float

Planned
Critical
Late Dates
Milestone
Progress
Summary
Float

Activity ID	Activity Desccription	Activity Type	Duration	Float	Early Start	Early Finish	Late Start
2.1.4.1.1	Revw, Revise & Modify Pass Two IC Proto Des to Provide	ASAP	20d	186d	03Oct05	28Oct05	23Jun06
2.1.4.1.2	Schematic Mods to Pass Two IC Proto to Create Final Des	ASAP	25d	186d	31Oct05	06Dec05	24Jul06
2.1.4.1.3	Sim Final IC	ASAP	20d	186d	07Dec05	03Jan06	28Aug06
2.1.6.1.4	Layout Final IC Design	ASAP	50d	186d	04Jan06	14Mar06	26Sep06
2.1.4.1.4	Sim Layout, Incorporate Des Changes & Revise Doc, as necessa	ASAP	20d	186d	15Mar06	11Apr06	07Dec06
2.1.6.1.5	Sim Layout, Incorporate Des Changes & Revise Doc, as necessa	ASAP	20d	186d	15Mar06	11Apr06	07Dec06
2.1.4.1.7	Lev5Rvw: Rvw Final IC Schems, Sims, Layout & Lad Test Res	ASAP	3d	186d	12Apr06	14Apr06	08Jan07
2.1.6.1.8	Lev5Rvw: Rvw Final IC Schems, Sims, Layout & Lad Test Res	ASAP	3d	186d	12Apr06	14Apr06	08Jan07
2.1.4.1.9.5	Obt Approvals for & Order Pre-Prod Run of Final ICs	ASAP	10d	186d	17Apr06	28Apr06	11Jan07
2.1.6.1.10.4	Obt Approvals for & Order Pre-Prod Run of Final ICs	ASAP	10d	186d	17Apr06	28Apr06	11Jan07
2.1.2.2.3.1	Vend Manfucture & Del Pre-Prod Run of Final ICs	ASAP	60d	186d	01May06	25Jul06	26Jan07
2.1.2.2.4	Test Pre-Prod Run of Final ICs	ASAP	40d	186d	26Jul06	20Sep06	20Apr07
2.1.2.2.5.1	Thinning, Coating & Dicing Tested Pre-Prod IC	ASAP	15d	186d	21Sep06	11Oct06	18Jun07
2.1.2.2.5.2	Obt Appr for & Transp Tested Pass Three IC Proto (Hyb A	ASAP	10d	186d	12Oct06	25Oct06	10Jul07
2.2.3.11	Send Proto Hybrids & Pass Three ICs to Vend for Assembly	ASAP	5d	186d	26Oct06	01Nov06	24Jul07
2.2.3.12	Vend Assembles & Tests Hybrids with Pass Three ICs	ASAP	20d	186d	02Nov06	01Dec06	31Jul07
2.2.8.3	Vend Assembles & Tests Hybrids with Pass Three ICs	ASAP	20d	186d	02Nov06	01Dec06	31Jul07
2.2.3.13	Test Assembled Preproduction Hybrids for Station Tests	ASAP	40d	186d	04Dec06	31Jan07	28Aug07
2.2.8.4	Test Assembled Preproduction Hybrids for Station Tests	ASAP	40d	186d	04Dec06	31Jan07	28Aug07
2.2.3.14	Lev4Rvw: Rvw Preproduction Hybrid Test Data	ASAP	5d	186d	01Feb07	07Feb07	24Oct07
2.2.4.1	Lev5Rvw: Rvw Hybrid Perfance in all the prototyping phases	ASAP	20d	186d	08Feb07	07Mar07	31Oct07
2.2.4.3	Rewrite, if necessary, Hybrid Reqmts & Specs	ASAP	10d	186d	08Mar07	21Mar07	30Nov07
2.2.4.4	Lev5Rvw: Rvw Hybrid Reqmts & Specs Document	ASAP	2d	186d	22Mar07	23Mar07	14Dec07
2.2.4.6	Design Production Hybrids	ASAP	10d	186d	26Mar07	06Apr07	18Dec07
2.2.4.7	Layout Production Hybrids	ASAP	15d	186d	09Apr07	27Apr07	07Jan08
2.2.4.8.1	Manufacture 1st Shipment of Hybrid	ASAP	90d	186d	30Apr07	05Sep07	29Jan08
2.2.9.1	Manufacture 1st Shipment of Hybrid	ASAP	90d	186d	30Apr07	05Sep07	29Jan08
2.2.4.8.3	Lev5Rvw: Ship 1st Shipment of Hybrid	ASAP	5d	186d	06Sep07	12Sep07	04Jun08
2.2.4.8.5	Perf Accept Test of 1st Shipment of Hybrid	ASAP	5d	186d	13Sep07	19Sep07	11Jun08
2.2.4.8.6	Lev5Rvw: Rvw 1st Shipment Hybrid Test Results	ASAP	2d	186d	20Sep07	21Sep07	18Jun08
2.2.4.9.1	Manufacture Final Shipment of Hybrid	ASAP	30d	186d	24Sep07	02Nov07	20Jun08
2.2.9.3	Manufacture Final Shipment of Hybrid	ASAP	30d	186d	24Sep07	02Nov07	20Jun08

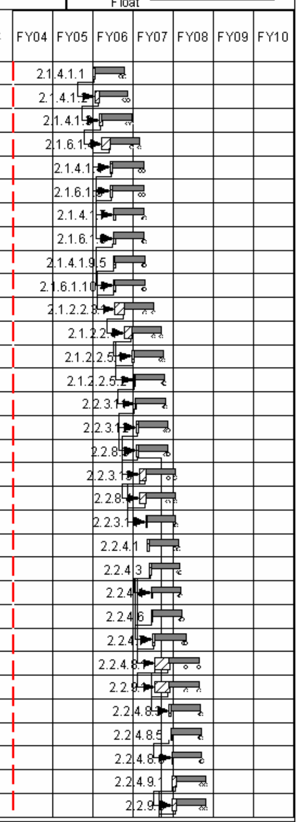
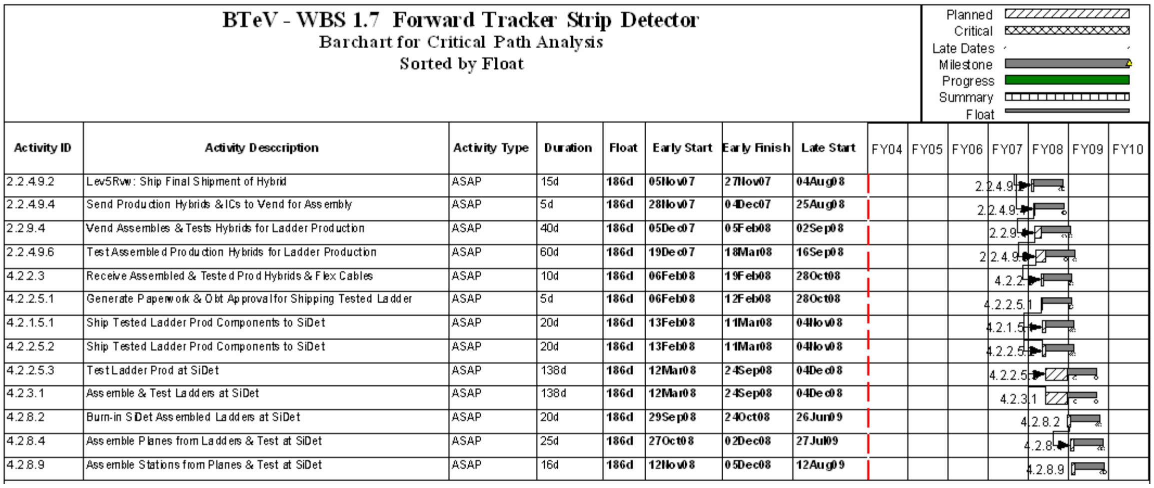


Figure 52: Critical Path Analysis from Open Plan



BTeV - WBS 1.7 Forward Tracker Strip Detector
Barchart for Critical Path Analysis
Sorted by Float

Activity ID	Activity Desccription	Activity Type	Duration	Float	Early Start	Early Finish	Late Start
2.2.4.9.2	Lev5Rvw: Ship Final Shipment of Hybrid	ASAP	15d	186d	05Nov07	27Nov07	04Aug08
2.2.4.9.4	Send Production Hybrids & ICs to Vend for Assembly	ASAP	5d	186d	28Nov07	04Dec07	25Aug08
2.2.9.4	Vend Assembles & Tests Hybrids for Ladder Production	ASAP	40d	186d	05Dec07	05Feb08	02Sep08
2.2.4.9.6	Test Assembled Production Hybrids for Ladder Production	ASAP	60d	186d	19Dec07	18Mar08	16Sep08
4.2.2.3	Receive Assembled & Tested Prod Hybrids & Flex Cables	ASAP	10d	186d	06Feb08	19Feb08	28Oct08
4.2.2.5.1	Generate Paperwork & Obt Approval for Shipping Tested Ladder	ASAP	5d	186d	06Feb08	12Feb08	28Oct08
4.2.1.5.1	Ship Tested Ladder Prod Components to SiDet	ASAP	20d	186d	13Feb08	11Mar08	04Nov08
4.2.2.5.2	Ship Tested Ladder Prod Components to SiDet	ASAP	20d	186d	13Feb08	11Mar08	04Nov08
4.2.2.5.3	Test Ladder Prod at SiDet	ASAP	138d	186d	12Mar08	24Sep08	04Dec08
4.2.3.1	Assemble & Test Ladders at SiDet	ASAP	138d	186d	12Mar08	24Sep08	04Dec08
4.2.8.2	Burn-in SiDet Assembled Ladders at SiDet	ASAP	20d	186d	29Sep08	24Oct08	26Jun09
4.2.8.4	Assemble Planes from Ladders & Test at SiDet	ASAP	25d	186d	27Oct08	02Dec08	27Jul09
4.2.8.9	Assemble Stations from Planes & Test at SiDet	ASAP	16d	186d	12Nov08	05Dec08	12Aug09

Figure 53: Critical Path Analysis from Open Plan

In Figure 54 we report the relative total construction obligation by fiscal year and in Figure 55 the total labor profile.
The singular shape of the total cost profile is driven by the sensor procurement, which for budget reasons is delayed to FY 2008.

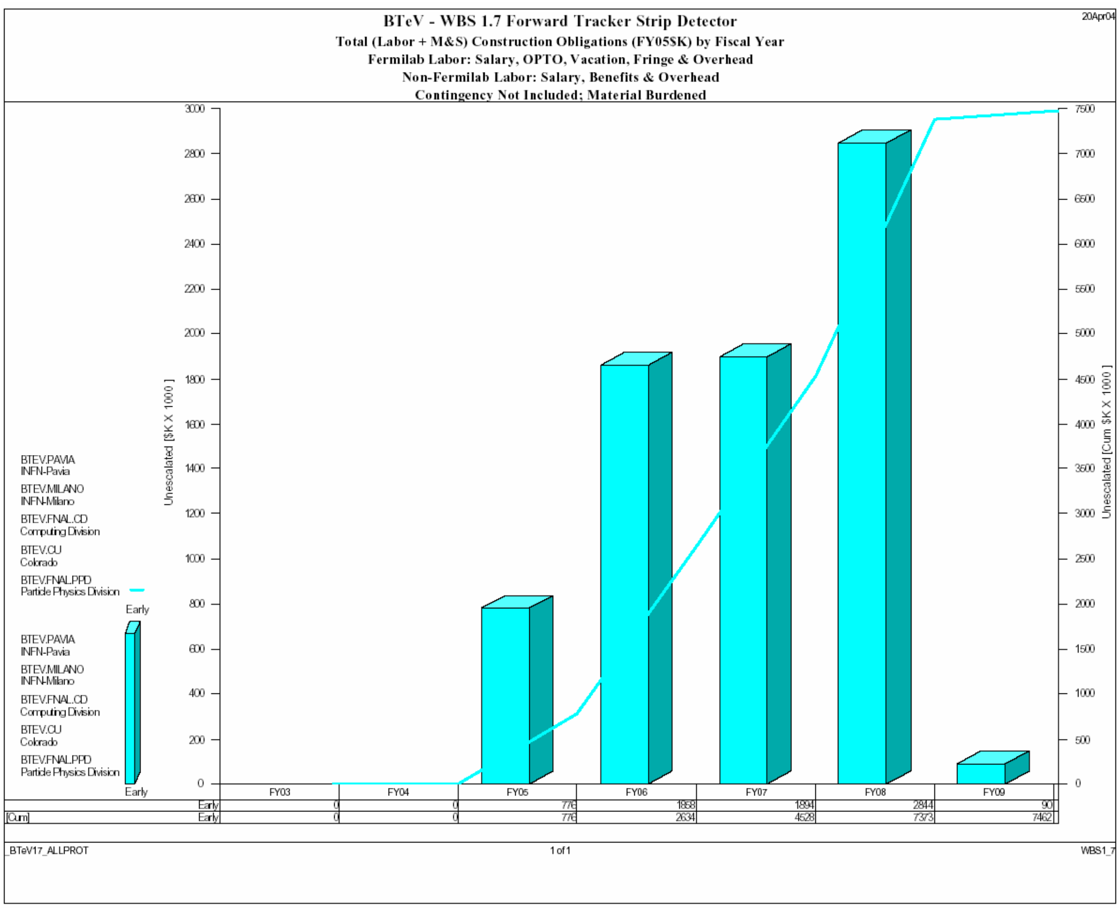


Figure 54: Total Construction Obligation by Fiscal Year

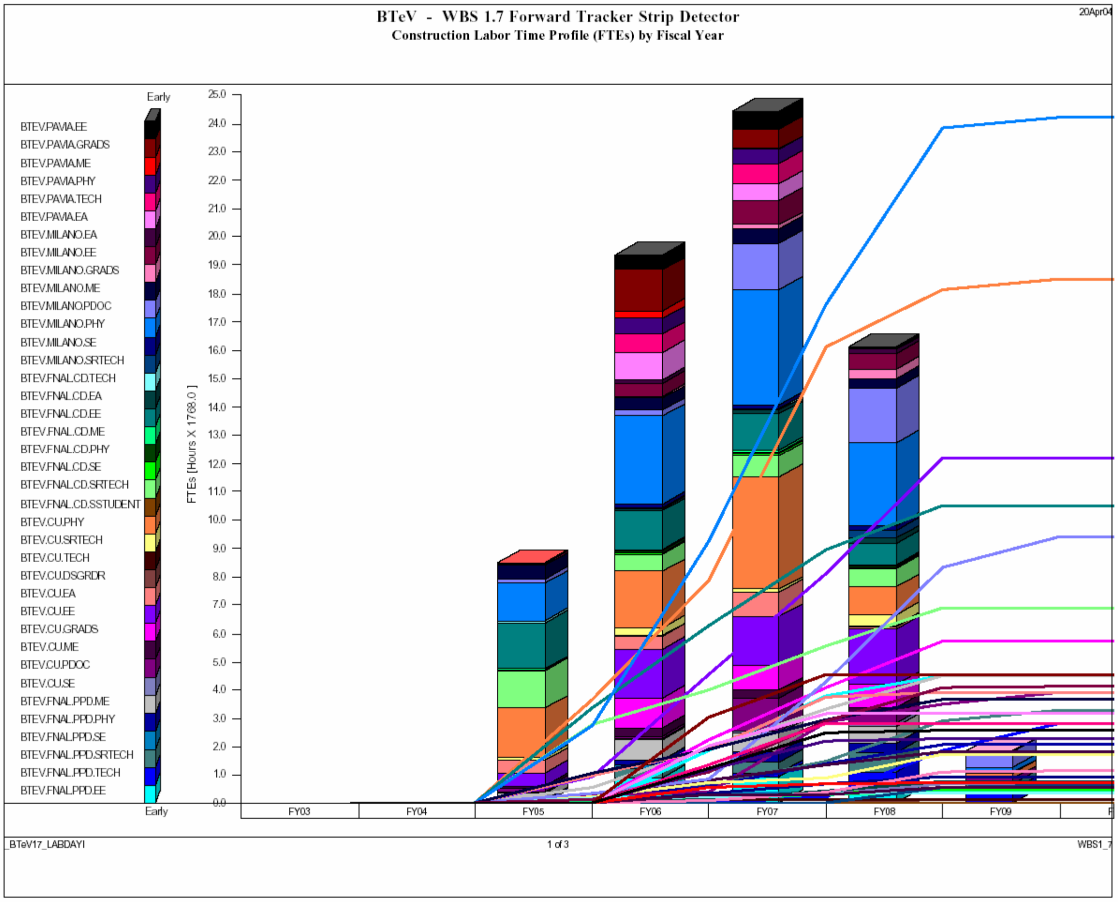


Figure 55: Total Construction Labor by Fiscal Year

7.7.2.1 Installation

Since Micro-Strip stations are individual and well separate entities, they are perfectly suited for a staged installation scenario. The only constraint that should be recalled is that to complete a single station-installation, including a full check of the station functionality and performance, a minimum time of about 3 days is required.

7.7.2.2 Impact of INFN funding

As anticipated in the introduction, subject to some conditions, we could profit of INFN early funding, which could really help us mainly in FY2005 to speed up the construction. INFN is considering to fund all the M&S of the Micro-Strip system, plus obviously the labor contributed by the Italian groups. This would amount to about 3.6 M$ of base M&S, plus 0.3 M$ of base Labor, for a total of about 7 M$ + contingency.

In this perspective, we could anticipate several activities on the critical path to FY2005 and benefit of three additional months of float, 12 months instead of 9. Furthermore, we could also anticipate the procurement of the final sensors of eight months, from Oct07 to Feb07, and relax the schedule, which, now, is quasi-critical. Generally speaking, the INFN funding would make our schedule particularly robust since it would remove from the critical path all the activities that in principle could stay out.

7.7.3 Response to CD-1 recommendations

We just got two minor recommendations:

1. "Reevaluate the contingency assigned to currency fluctuation for procurements from foreign companies" – This was probably due to a miss-communication between me and the reviewers, since I am using the same contingency rules as in all the other projects;
2. "Move the engineering costs from WBS item 1.7.6 (Project Management) to their appropriate places" -- I agree on and immediately executed.

7.8 Schedule for Trigger System (WBS 1.8)

7.8.1 Introduction

7.8.1.1 Brief Desciption

BTeV has a sophisticated trigger system that rejects at least 99.9% of light-quark background events while retaining large numbers of *B* decays for physics analyses. The trigger supports BTeV's goal to acquire a large number and a broad range of *B* decays using many different *B*-tagging techniques. The design of the trigger takes advantage of the high-resolution three-dimensional tracking data provided by the pixel vertex detector, is based on a consistent trigger strategy throughout all three stages of the trigger system, analyzes every bunch crossing to search for evidence of a *B* decay, and includes software to implement a fault tolerant and fault adaptive trigger architecture.

7.8.1.2 Staging

In response to the DOE CD-1 Review of the BTeV Project, the schedule for the construction of the BTeV trigger has been modified to include two development stages. The first stage of the BTeV trigger consists of 50% of all trigger hardware. It also includes the final production version of all software required for the first and second level triggers (L1 and L2), and the second production release of software for the third level trigger (L3). The second stage of the trigger consists of 100% of all trigger hardware, and includes the final production version of the software for all trigger levels. To satisfy the

CD-1 Review recommendations, we have adjusted the WBS 1.8 cost profile by shifting more than 2000 K$ from FY09 to FY08 and more than 400 K$ from FY07 to FY06.

The approach that BTeV will use to build a 50% trigger system (and 50% of the data acquisition system) is to take advantage of the system architecture. Since the architecture of the trigger and data acquisition system (DAQ) consists of eight parallel trigger/DAQ *highways* that operate independently of each other, we can easily implement 50% of the system by building four of the eight trigger/DAQ highways.

The 50% trigger system includes the following:

- 50% of the L1 pixel trigger hardware
- 100% of the L1 pixel trigger software
- 100% of the Global Level 1 (GL1) hardware and software
- 50% of the L2/3 trigger hardware
- final production release of L2 trigger software
- second production release of L3 trigger software

The design of the trigger system includes a factor of two safety margin for bandwidth, and assuming a factor of four increase in computational power over the next four years we expect to be able to operate the trigger at a peak design luminosity of 2×10^{32} cm^{-2} s^{-1} with four of the eight trigger highways. If the capacity of the 50% trigger /DAQ system is not quite adequate during periods of peak luminosity (for example, at the beginning of a Tevatron store) then a fraction of the data can be dropped (by directing data to non-existent highways) until the luminosity has decreased to a level where all of the data can be processed.

The remainder of the hardware and software will be included in the trigger when 100% of the trigger system has been completed. This includes the following:

- the remaining 50% of the L1 pixel trigger hardware
- 100% of the L1 muon trigger
- the remaining 50% of the L2/3 trigger hardware
- final production release of L3 trigger software

7.8.2 Project Flow & Cost

The project flow for the BTeV trigger system is shown in Figure 56. The critical path is shown in red for both the Stage 1 detector and the complete detector. For the Stage 1 detector the 50% L1 Farm and 50% L1 PP&ST (pixel processor and segment tracker) are both on the critical path (they have the same duration and float), since the two subsystems have comparable complexity and are therefore assigned the same length of time for design, procurement, fabrication, and testing.

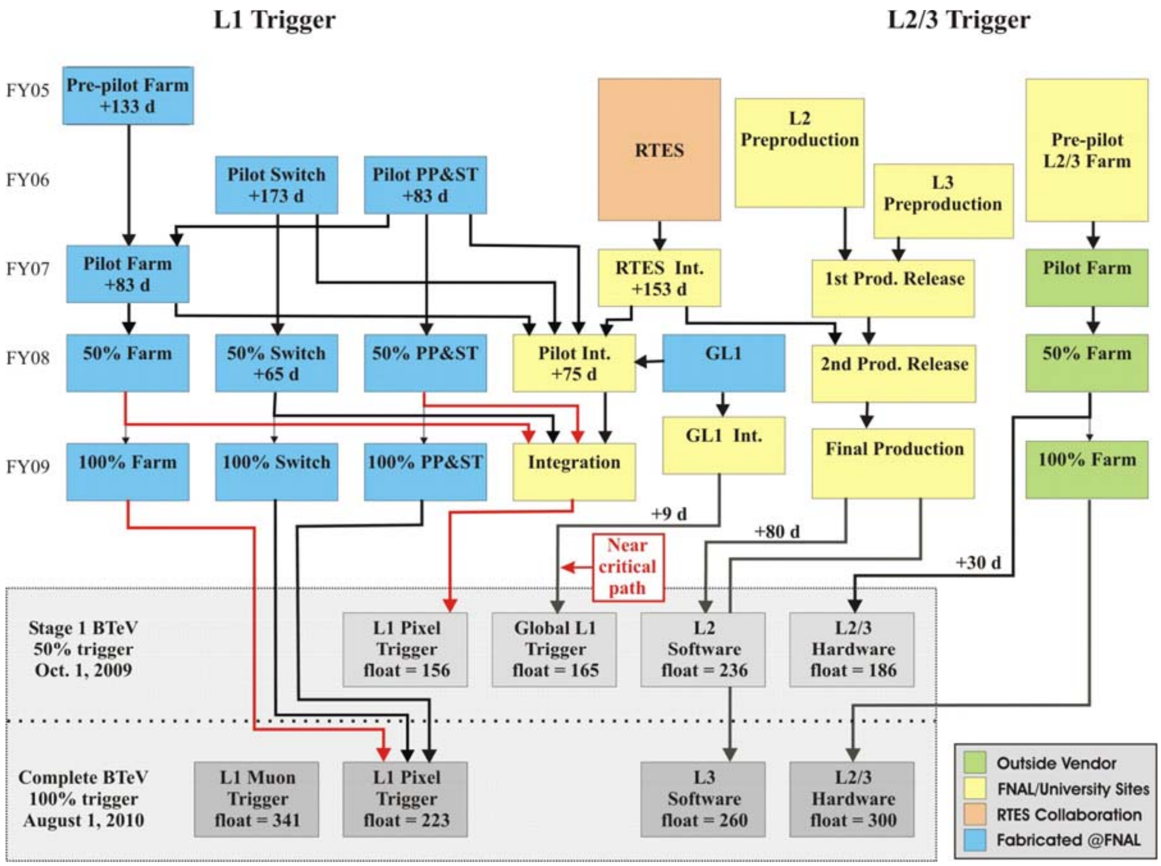


Figure 56: Project Flow

A near-critical path is also identified in Figure 56. The fabrication of the Global Level 1 (GL1) trigger is coupled to the fabrication of the 50% L1 pixel trigger, since the same processing hardware is used for both subsystems. The fabrication of GL1 has an additional nine workdays of float relative to the critical path. This is indicated by the "+9" label in the figure.

Figure 57 shows the same high-level activities for WBS 1.8 in the form of a Gantt chart. The activities on the critical path are shown in red. In this figure there are two sets of activities that are shown in red. The first set of activities corresponds to the design, fabrication, and testing of the first two of eight L1 pixel trigger highways. The second set of activities corresponds to the next two highways, which begin at a later date since they do not include the initial design phase but overlap in time for fabrication and testing of the highways.

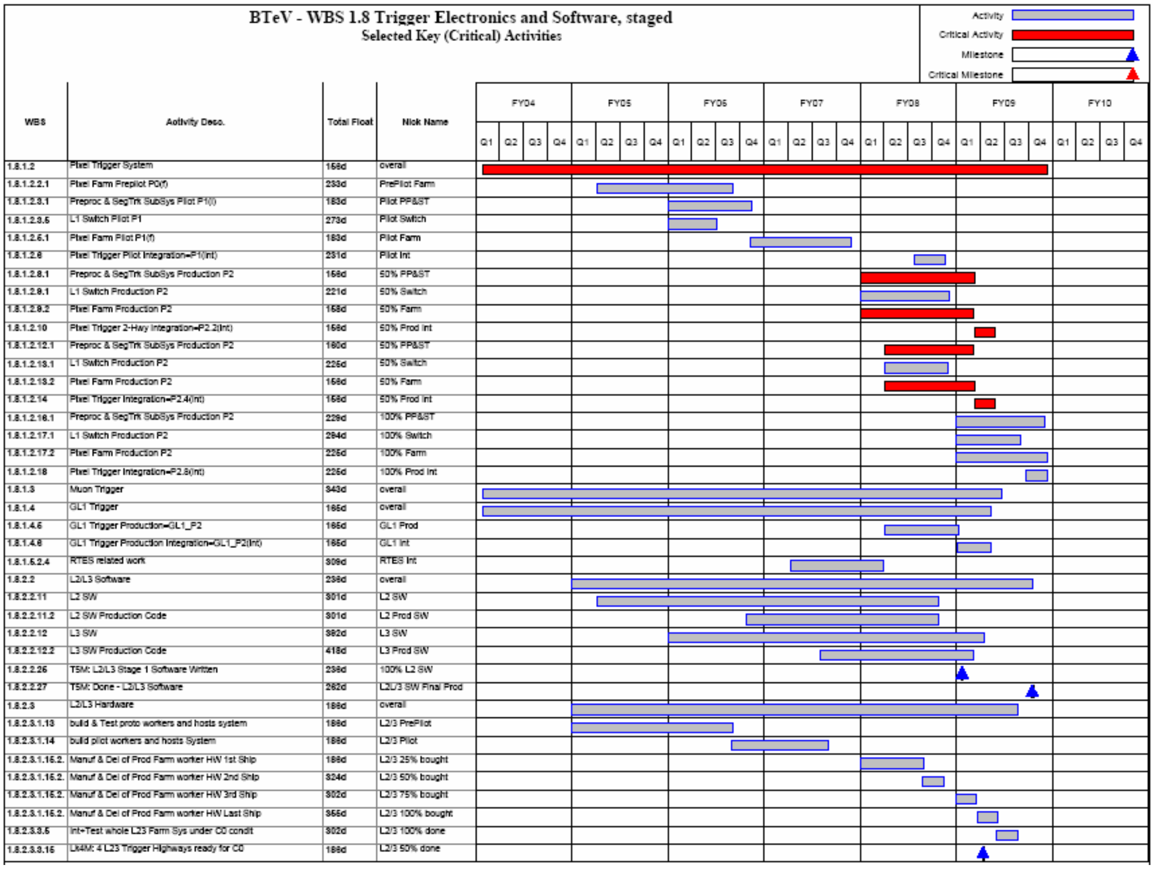


Figure 57: Project Gantt Chart

Two types of target dates are used to characterize the schedule for the BTeV trigger system. These are the Need-by dates and Ready-by dates, which are shown in Table 24.

Milestone	Ready By Dates	Need By Dates	Total Float
50% trigger	February 23, 2009	October 1, 2009	7 months
100% trigger	September 8, 2009	August 1, 2010	10.5 months

Table 24: Ready By and Need By Dates for WBS 1.8

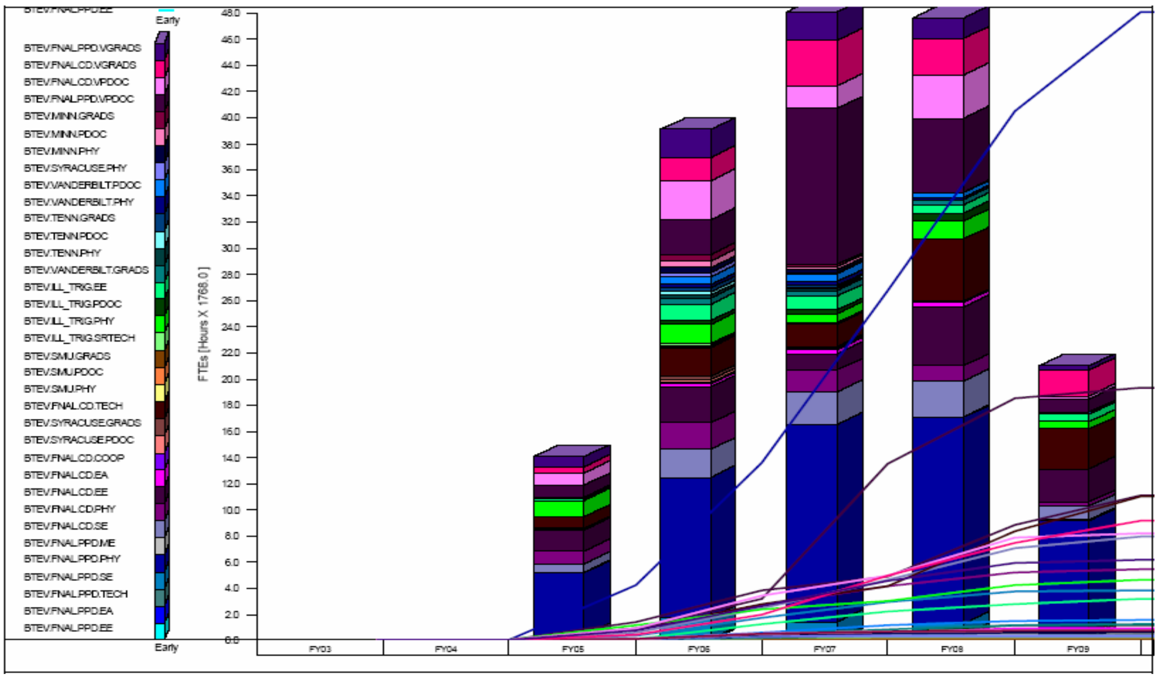


Figure 58: Labor Profile

Figure 58 shows the labor profile for WBS 1.8 in units of FTEs. For each of the five construction years beginning in FY05, we estimate that we need the following numbers of FTEs: 14, 40, 48, 48, and 21.

Periods of peak activity occur in FY07 and FY08. During FY07 the Pilot systems for L1 and L2/3 are developed, so that a complete trigger highway is ready by the end of 2007. During FY08 the experience that has been gained with the Pilot systems will be applied to the development of the four trigger highways that are built for the Stage 1 detector.

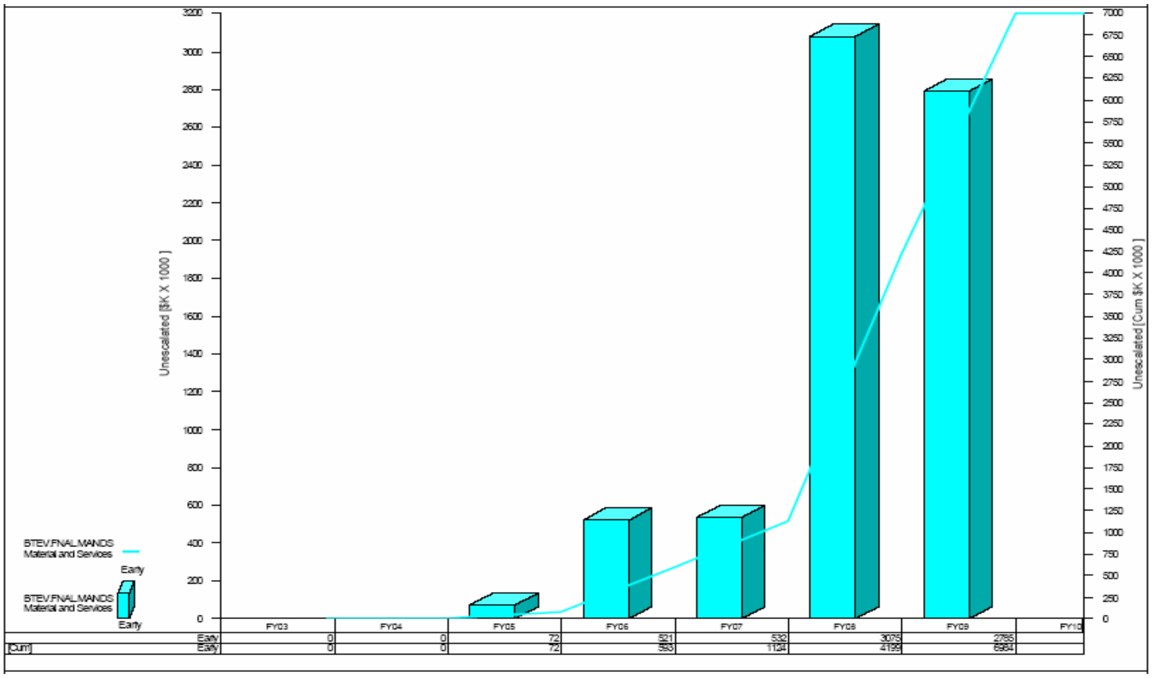


Figure 59: M&S Obligation Profile

Figure 59 shows the M&S obligation profile for each of the five construction years (beginning in FY05): 72 K$, 521 K$, 532 K$, 3075 K$, and 2785 K$. Spending in the first three years is for equipment that is needed to develop the Pre-pilot L1 Farm and Pilot L1 and L2/3 trigger systems. Most of the spending is delayed until FY08 and FY09 to obtain the best performance for the lowest price for electronics hardware (FPGAs, DSPs, and commercial processors).

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.8.1	L1 Hardware & Software	7,515,289	32	33	471,742	1,428,245	1,080,605	4,233,133	2,744,333	9,958,059
1.8.2	L2/L3 Hardware & Software	4,227,880	34	89	212,360	1,041,803	1,049,699	2,285,622	2,133,344	6,722,829
1.8.3	Trigger Electronics & SW Subproj Mgmt	401,262	16	24	99,285	100,867	99,681	99,681	94,538	494,052
1.8	**Subproject 1.8**	**12,144,431**	**33**	**53**	**783,388**	**2,570,916**	**2,229,985**	**6,618,435**	**4,972,216**	**17,174,940**

Table 25: WBS 1.8 Base Cost, Contingency, and Total Cost by Fiscal Year

The base cost, contingency, and total cost by fiscal year are shown in Table 25 for the three highest-level activities for WBS 1.8.

	FY05	FY06	FY07	FY08	FY09	Total
CD-1	637K	2,150K	2,651K	4,506K	7,103K	17,046K
Staged	783K	2,571K	2,230K	6,618K	4,972K	17,175K
Net Change	146K	421K	(421K)	2,112K	(2,131K)	129K

Table 26: Cost Profile Change for Staged Installation

Table 26 shows a comparison of the total cost for each fiscal year for cost estimates presented at the DOE CD-1 Review, and the modified cost estimates for the staged detector. The last row shows the net change in cost estimates for WBS 1.8. There is an overall increase of 129 K$ that results from a shift in funding for electronics equipment from FY08 to FY09. Hardware expenditures in FY08 (for four of eight trigger highways) are higher compared to comparable hardware purchases in FY09.

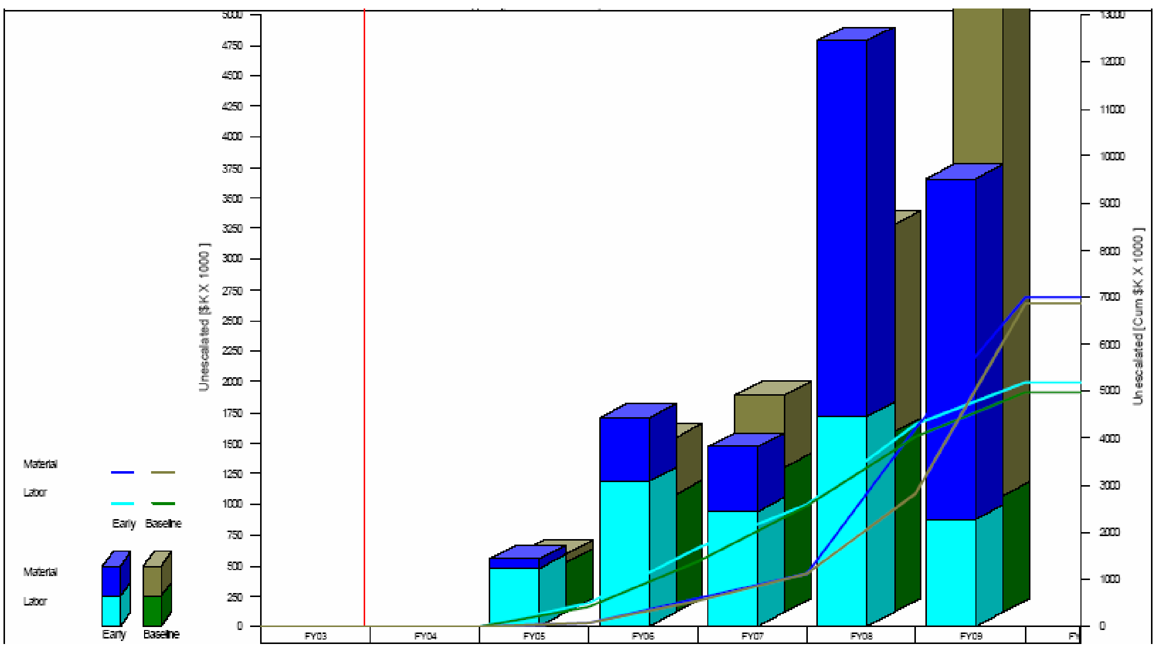


Table 27: WBS 1.8 Base Cost before and after the CD-1 Review

In response to the CD-1 recommendations (see next section) we modified the schedule for WBS 1.8, and this resulted in changes to the cost profile. The biggest changes in the schedule were the following:

- We moved the start of L2 software development to an earlier date, so that the software development and testing is completed almost 12 months before the

Need-by date for the Stage 1 detector. This change requires approximately 140 K$ more for labor in FY05.

- We moved the fabrication and testing of two trigger highways from FY09 to FY08, so that 50% of the trigger is completed seven months before the Need-by date for the Stage 1 detector. This change requires a shift in funding of more than 2000 K$ from FY09 to FY08.
- We introduced additional float in the schedule for the L1 Pilot system. This change requires a shift in funding of more than 400 K$ from FY07 to FY06.

7.8.3 Response to CD-1 Recommendations

There were three recommendations that emerged from the DOE CD-1 Review of the BTeV Project:

1) Develop a schedule which (a) completes critical design and validation activities as soon as possible and is ready for production six to nine months in advance of the production start date, and (b) completes production of the trigger and data acquisition systems six to nine months in advance of first collisions.

We have developed a schedule that completes 50% of the L1 trigger seven months before the Need-by date for the Stage 1 detector (Oct. 1, 2009), and completes 50% of the L2/3 trigger more than eight months before the Need-by date. This was accomplished by moving more than 2000 K$ from FY09 to FY08 so that a total of four highways can be built in FY08.
Critical design and validation activities for the trigger have been an ongoing effort for the BTeV trigger group. We will complete an L1 Pilot system (one highway) for the PP&ST and L1 Switch almost 14 months prior to the start of production on October 1, 2007.

2) Re-evaluate the basis of estimate of the FPGA costs to allow for uncertainty in the de-escalation profile.

We will evaluate the basis of estimate for FPGA costs, and may adopt the same approach that is being considered for WBS 1.9.

3) Quickly identify and apply new individuals and groups to provide the physicist effort called for by the WBS.

We have started to identify new individuals and groups to provide the physicist effort for WBS 1.8.

7.8.4 Risk Table & Mitigation Strategies

The development of the BTeV trigger has moderate risks compared to other BTeV systems, since components of the trigger system are within the realm of technology that is available today. The hardware will consist of commodity or mid-life components when the hardware is purchased in order to meet budgetary constraints. Another factor moderating risk is the fact that many of the modules or subsystems have existing examples or prototypes that are functionally representative of what is needed for the trigger, even if they do not meet some of the needed performance specifications. The required increase in performance is conservative within the range of historical projection and manufacturers' estimates of how the technology will advance during the R&D and design period of the experiment. Therefore, we believe that our prototypes are applicable to projections of cost, schedule, and risk.

The baseline design of the trigger system makes extensive use of Field Programmable Gate Arrays (FPGAs), data links, Digital Signal Processors (DSPs), and commodity PC workstations. The performance of these basic technologies has advanced at such a consistent rate that conservative predictions of the performance have a low risk factor. However, specific risk issues are addressed in Table 4.

WBS number	**Risk Event**	**Probability**	**Impact**	**Severity**	**Mitigation Plans/Options**
Most of them	Experienced people leave the trigger project.	Moderate 0.49-0.25	High Risk 0.4	.15	Be sure that more than one person is working on critical tasks. Use contingency funds to hire the person who is leaving as a temporary consultant while their expertise is transferred to existing or new personnel.
For example 1.8.1.2.2.2.2	Baseline processor fails to meet the specified requirements.	Moderate 0.49-0.25	High Risk 0.4	.15	Benchmark and qualify more than one processor during R&D or early construction phase. Have a 2nd option ready if 1st option is unsatisfactory.
For example 1.8.1.2.13.1, 1.8.1.2.13.2, 1.8.1.2.14.1	Cost of large FPGAs used throughout the L1 trigger system does not have the reductions estimated using history and Moore's law.	Moderate 0.49-0.25	Moderate Risk 0.2	.07	Plan to survey FPGA options regularly. Plan for algorithms that can be partitioned into smaller devices or implemented using different type of devices. To save costs, study simplifying the algorithm and its effect on performance and efficiency. Use contingency funds.

For example 1.8.1.2.4.1.2, 1.8.1.3.1.2	Pixel Segment Tracker or Muon Preprocessor algorithm exceeds the size of the selected FPGA. Larger FPGA increases the cost.	Moderate 0.49-0.25	High Risk 0.4	.15	Use contingency funds to upgrade to a bigger and more expensive FPGA. Consider other implementation alternatives early in the design stage. Consider simplifying the Pixel Segment Tracker or Muon Preprocessor algorithm(s).
For example 1.8.1.2.13.1.2.2.2, 1.8.1.2.14.2.2.2.3	Long lead times in ordering of critical parts.	High 0.60-0.50	Low Risk 0.1	.05	Order parts early. Do not freeze the design until all the parts are purchased or available. Have a substitute in case a critical part becomes unavailable. May require contingency funds.
For example 1.8.1.2.13.1.2.2.1, 1.8.1.2.14.2.2.2.1	PC board fabrication and/or assembly delayed by contract problems or company schedule slippage.	Moderate 0.49-0.25	Moderate Risk 0.2	.07	Qualify more than one vendor for the job. Contract based on fixed schedule. Use contingency to pay for faster turnarounds.
For example 1.8.1.2.13.2	Communication links perform below error rate specifications.	Moderate 0.49-0.25	High Risk 0.4	.15	Use contingency funds to redo PC boards, buy new parts, connectors or cables.
For example 1.8.1.2.8.2.3.3, 1.8.2.2.8	Shortage of software developers	Moderate 0.49-0.25	High Risk 0.4	.15	Prioritize critical tasks. Use contingency funds to hire a software programmer temporarily.
1.8.1.3.2	Incompatibility between the pixel trigger solution and the muon trigger requirements	Moderate 0.49-0.25	Moderate Risk 0.2	.07	Avoided by active communications; detected through collaborative testing; mitigated by FPGA reconfiguration (Buffer Manager, Muon Preprocessor), and/or a larger Muon DSP farm, built with “additional” boards from both (pixel, muon).
1.8.2.3	Backgrounds larger than in simulations affecting rejection	Moderate 0.49-0.25	Moderate Risk 0.2	.07	Prioritize physics triggers and adjust L2/3 algorithms selection criteria so that the rejection rate can be increased while still allowing acceptable efficiency. Design algorithms with possible increased background in mind.
1.8.2.2	Event size is larger than expected due to higher backgrounds than in simulations or need for raw information.	Moderate 0.49-0.25	Low Risk 0.1	.04	If it is a temporary situation due to testing or debugging, then accept larger data size at L3. Spend contingency to get larger data buffering. Else prioritize data to be kept based on physics goals and prescale or increase prescale on lower priority information.

1.8.2.3	Events are more complicated than in simulations and take more CPU resources than in simulation.	Moderate 0.49-0.25	Low Risk 0.1	.04	Optimize L2/3 trigger algorithms and PC farm framework software. If needed prioritize the processing based on physics goals. Spend contingency to get faster CPUs.
1.8.2.2.10.5	RTES does not provide enough monitoring and fault tolerant software in a timely manner for the trigger.	Low 0.24-0	Low Risk 0.1	.02	Ensure individual software projects themselves have enough monitoring software. Prioritize monitoring software projects to make sure the minimal amount of monitoring software is done.

Table 28: Risk Elements in the BTeV Trigger and Mitigation Plans

7.9 Schedule for Data Readout and Control (Data Acquisition) System (WBS 1.9)

7.9.1 Introduction

7.9.1.1 Brief Description

In response to the DOE CD-1 Review of the BTeV Project, the schedule for the construction of the BTeV Data Acquisition has been modified to include two development stages. The first stage contains 50% of the DAQ electronics hardware (excluding the archiving storage system) and enough of the readout software to support partitioning. The second stage of the DAQ encompasses the completion of all of WBS 1.9 electronics and software with the exception of the hardware and software support activities that will continue through the end of construction.

7.9.1.2 Staging

The DAQ and Trigger stages are constructed in the same manner – that is building a highway at a time. Thus, the 50% completion milestone refers to the completion of 4 of the 8 highways.

The 50% DAQ system includes the following:
- 50% of the DCB Hardware
- 50% of the L1 Buffer Hardware
- 50% of optical links
- 100% of the timing system
- 100% of the networking

- 100% of the slow controls system
- The third major release of run control: that which includes partitioning
- All database applications with the exception of Slow Controls Archiving

The design of the DAQ system includes a safety margin for bandwidth and we expect to be able to operate at a peak design luminosity of 2×10^{32} cm^{-2} s^{-1} with less than eight highways. If the capacity of the 50% system is not quite adequate during periods of peak luminosity (for example, at the beginning of a Tevatron store) then a fraction of the data can be dropped (by directing data to non-existent highways) until the luminosity has decreased to a level where all of the data can be processed.

The remainder of the hardware and software will be included in the readout and controls system when 100% of the RCS has been completed. This includes the following:

- the remaining 50% of the electronics
- 100% of the mass storage system
- 100% completion of the run control software
- 100% of the database applications

7.9.2 Project Flow & Cost

The overall project flow is shown in Figure 60. The critical paths through the project are on three parallel routes – the production of the custom electronics, the completion of data archival software, and the completion of the databases. Figure 61 shows a Gantt chart view, mapping 50% completion of the DCBs and Production Readout Software.

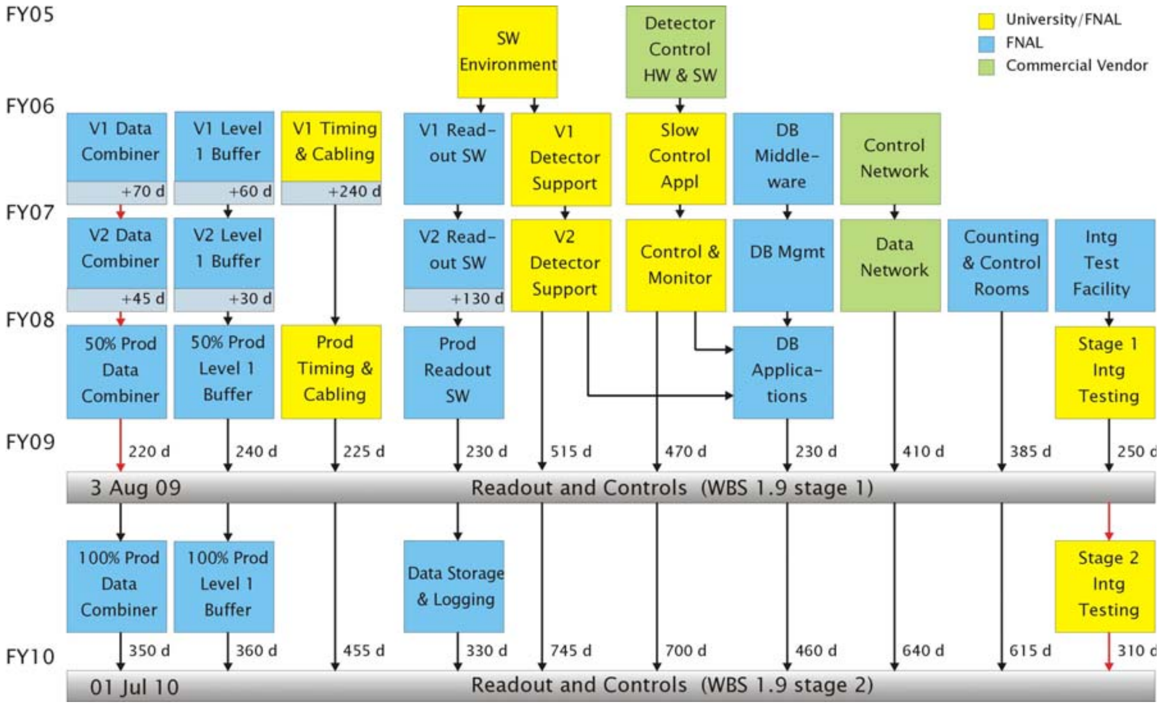
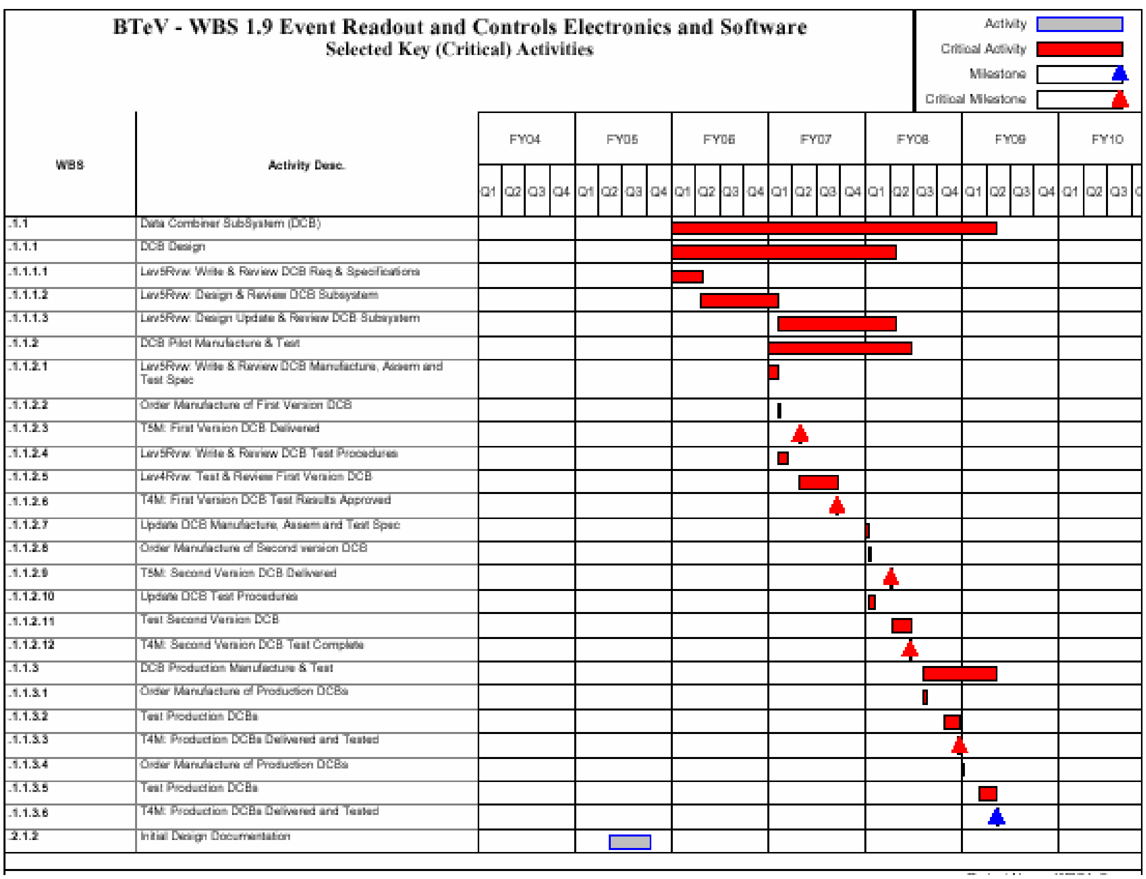


Figure 60: WBS 1.9 Project Flow



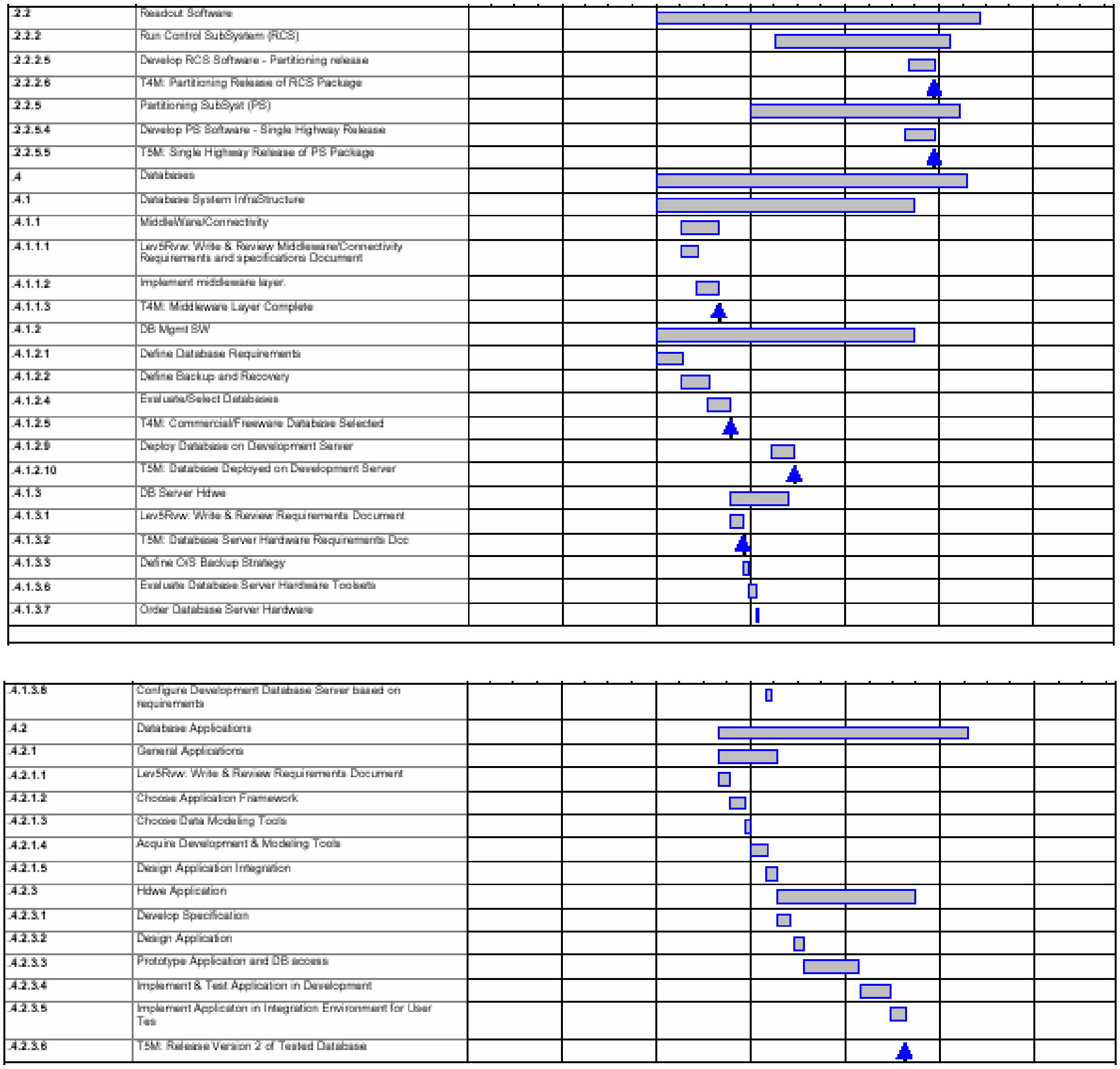


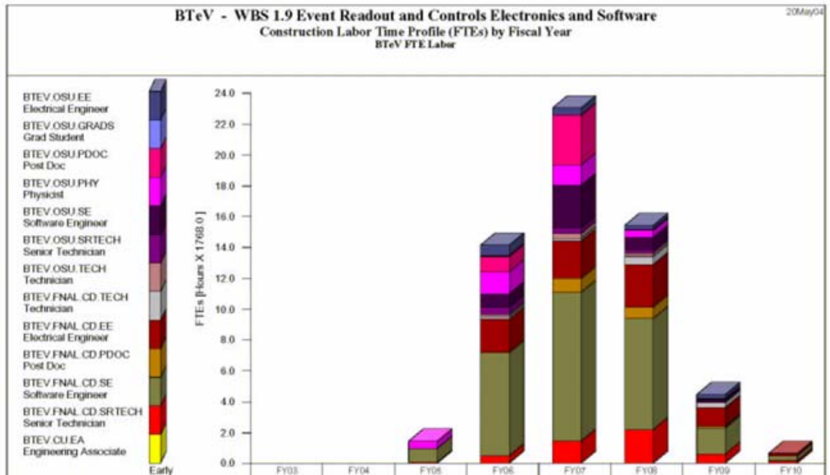
Figure 61: WBS 1.9 Gantt Chart

Table 29 shows the critical path dates.

Milestone	Ready by date	Need by date	Total Float
50% completion	September 12, 2008	3 Aug, 2009	11 months
100% completion	March 9, 2009	1 July, 2010	15 months

Table 29: Milestone Total Float

Figure 62 shows the labor profile for WBS 1.9 in units of FTEs.



	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
BTEV.CU.EA : Engineering Associate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BTEV.FNAL.CD.SRTECH : Senior Technician	0.0	0.0	0.0	0.5	1.4	2.1	0.6	0.1
BTEV.FNAL.CD.SE : Software Engineer	0.0	0.0	0.9	6.7	9.7	7.2	1.7	0.3
BTEV.FNAL.CD.PDOC : Post Doc	0.0	0.0	0.0	0.0	0.9	0.7	0.1	0.0
BTEV.FNAL.CD.EE : Electrical Engineer	0.0	0.0	0.0	2.2	2.4	2.8	1.2	0.1
BTEV.FNAL.CD.TECH : Technician	0.0	0.0	0.0	0.2	0.2	0.5	0.3	0.0
BTEV.OSU.TECH : Technician	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0
BTEV.OSU.SRTECH : Senior Technician	0.0	0.0	0.0	0.5	0.4	0.2	0.0	0.0
BTEV.OSU.SE : Software Engineer	0.0	0.0	0.0	0.9	2.7	0.8	0.2	0.0
BTEV.OSU.PHY : Physicist	0.0	0.0	0.5	1.4	1.4	0.5	0.0	0.0
BTEV.OSU.PDOC : Post Doc	0.0	0.0	0.0	1.0	3.2	0.1	0.0	0.0
BTEV.OSU.GRADS : Grad Student	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BTEV.OSU.EE : Electrical Engineer	0.0	0.0	0.0	0.7	0.5	0.3	0.2	0.0

_BTeV19_LABDAYI 1 of 1 WBS1_9

Figure 62: WBS 1.9 Labor Profile

Figure 63 shows the M&S obligation profile for each of the five construction years. Most of the spending is delayed until FY08 and FY09 to obtain the best price for electronics.

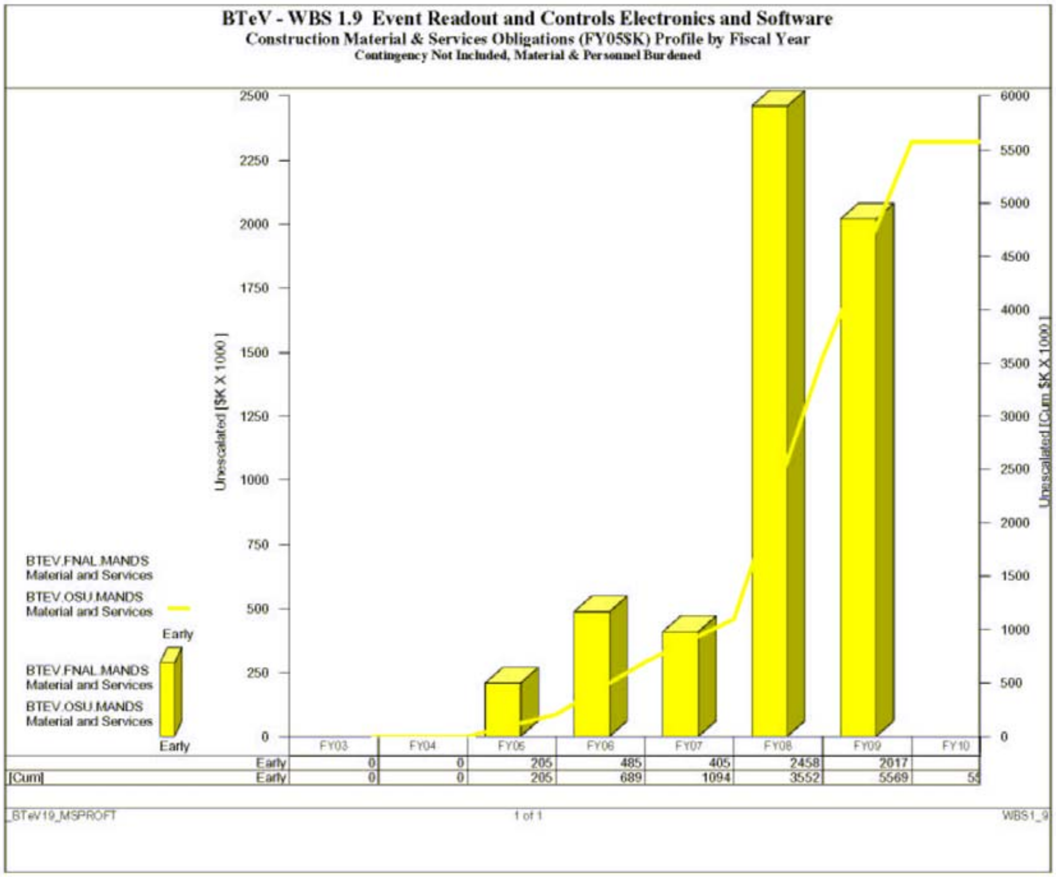


Figure 63: WBS 1.9 M&S Obligation Profile

Table 30 shows the base cost for the readout and controls system This table also shows the material and labor contingency, as well as the total cost (including contingency) for each fiscal year. Table 31 shows the net change for each fiscal year needed for the funding profile presented in the CD-1 review to accomplish the staged detector installation. FY10 costs are for general project support tasks and are not part of the critical path.

Activity ID	Activity Name	Base Cost($)	Material Contingency(%)	Labor Contingency(%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.9.1	Readout Electronics	4,872,820	43	30	0	485,154	918,290	3,233,489	2,139,950	6,776,884
1.9.2	Data Acquisition Software	2,483,823	37	31	401,726	634,595	801,660	381,096	1,087,277	3,306,353

1.9.3	Detector Control System	513,892	26	30	0	424,914	231,313	0	0	656,227
1.9.4	Databases	1,472,103	60	29	0	535,591	823,590	577,997	13,608	1,950,785
1.9.5	Control & Data Network	334,986	60	30	0	148,027	60,622	233,057	38,598	480,304
1.9.6	Infrastructure & Integration	1,129,843	34	30	0	34,384	344,550	1,071,868	36,911	1,487,713
1.9.7	Technical Support Activities	771,948	34	28	22,962	185,465	208,818	222,918	245,133	885,296
1.9.8	Readout & Controls Subproject Management	604,858	30	21	11,809	214,337	235,447	234,977	36,847	733,417
1.9	**Subproject 1.9**	**12,184,272**	**41**	**29**	**436,497**	**2,662,466**	**3,624,290**	**5,955,402**	**3,598,323**	**16,276,979**

Table 30: WBS 1.9 Cost

	FY05	FY06	FY07	FY08	FY09	FY10	Total
CD-1	393K	2,669K	3,571K	5,090K	4,614K	0	16,337K
Staged	436K	2,662K	3,624K	5,955K	3,598K	109K	16,386K
Net Change	43K	(7K)	53K	865K	(1016K)	109K	49K

Table 31: WBS 1.9Cost Profile Change for Staged Installation

The above changes address the CD-1 review recommendation that we complete the DAQ 6-9 months before first collisions and complete design and validation as soon as possible for critical activities. The following changes have been made to the profile since the CD-1 review:

- Moving half of the electronic purchases from FY09 to FY08 to allow for 50% completion in FY08
- Shifting PTA card purchases ($150K) from FY06 to FY05 (this was an oversight that was found and corrected).
- Some shuffling of activities with large floats to keep our funding profile as backloaded as we could.

7.9.3 Response to CD-1 Recommendations

There were three recommendations that emerged from the DOE CD-1 Review of the BTeV Project:

4) Develop a schedule which (a) completes critical design and validation activities as soon as possible and is ready for production six to nine months in advance of the production start date, and (b) completes production of the trigger and data acquisition systems six to nine months in advance of first collisions.

   WBS 1.9 Response: The original schedule had approximately 3 months of float at project completion, with an additional 4-5 months of distributed float. We were able to add 3 months of completion float through a better understanding of funding obligation rules (purchase order vs. purchase request dates). Another six months of float has been obtained by shifting half of the production hardware cost to FY08 and applying the staged schedule. This results in a total float of 12 months.

5) Re-evaluate the basis of estimate of the FPGA costs to allow for uncertainty in the de-escalation profile.

   WBS 1.9 Response: There are two approaches to estimating de-escalation costs of electronic components; 1) assume fixed cost, with an increasing level of performance, or 2) assume fixed performance, with decreasing cost. CD-1 reviewers seemed to be more comfortable with the "fixed price/increasing performance" approach and we will modify our estimates to follow this model.

   Example: the FPGA quoted in both the DCB and L1B subprojects has three current speed grades ("-5" @ $374, "-6" @ $523 and "-7" @ $734). We originally used the "-7" speed grade, with a de-escalation factor of 15% per year, resulting in a cost estimate (FY08) of $383. Applying a de-escalation of 7.5% to the "-6" cost, or 0% to the "-5" cost provides the same result.

   Therefore we are not expecting any significant change in the overall material cost estimate as a result of the change in de-escalation model.

6) Quickly identify and apply new individuals and groups to provide the physicist effort called for by the WBS.

   WBS 1.9 Response: This recommendation was less applicable to the DAQ subproject. However, we have moved some labor cost from physicist/postdoc categories to software and hardware engineering (particularly in system test and integration) and we expect additional university collaboration.

7.9.4 Risk Table & Mitigation Strategies

These have not changed from CD-1.

7.10 Schedule for Installation and Integration (I&I) Task (WBS 1.10)

7.10.1 Introduction

The purpose of this task is to coordinate the installation, integration and commissioning of the various detector components and the mechanical and electrical systems that comprise the BTeV spectrometer.

The BTeV detector is different from the two “central detectors," CDF and D0, currently operating in the B0 and D0 Interaction regions. CDF and D0 are hermetic detectors with a nested barrel geometry in which each barrel layer occupies a cylindrical annulus that is supported off of an adjacent radial layer. In contrast, BTeV has a more open linear geometry in which the large magnets and particle ID detectors occupy their own space along the beam line and are self-supporting. The forward tracking detectors are relatively lightweight and can be installed or removed without moving large objects around the collision hall. The installation, integration, and maintenance of a detector with this geometry is less demanding than for a hermetic, central region detector. It also permits a piecewise installation strategy. However, even with these advantages, the installation and integration of the BTeV detector in the small C0 enclosure will be a challenging task that will require careful planning and coordination.

Two things complicate the installation of the BTeV spectrometer. First of all, the C0 collision hall does not have a large crane, hence all components must be rolled into the hall. Secondly, the installation must not interfere with CDF and D0 data taking during Run II. The installation will need to occur during scheduled down days, upgrade shutdowns, and occasional repair periods of the Tevatron accelerator. The CD-1 review recommended that the schedule for the installation of the BTeV detector be reviewed and adjusted to allow more float for some of the technically more challenging BTeV detector construction projects. This review has resulted in some major changes in the schedule for this WBS1.10 subproject as outlined below.

Specifically, the schedule for the assembly of the large BTeV spectrometer components in the C0 Assembly Hall has been planned in detail. This has then influenced the schedule for the installation of the detector components costed in this WBS1.10 subproject.

7.10.2 Project Flow and Cost

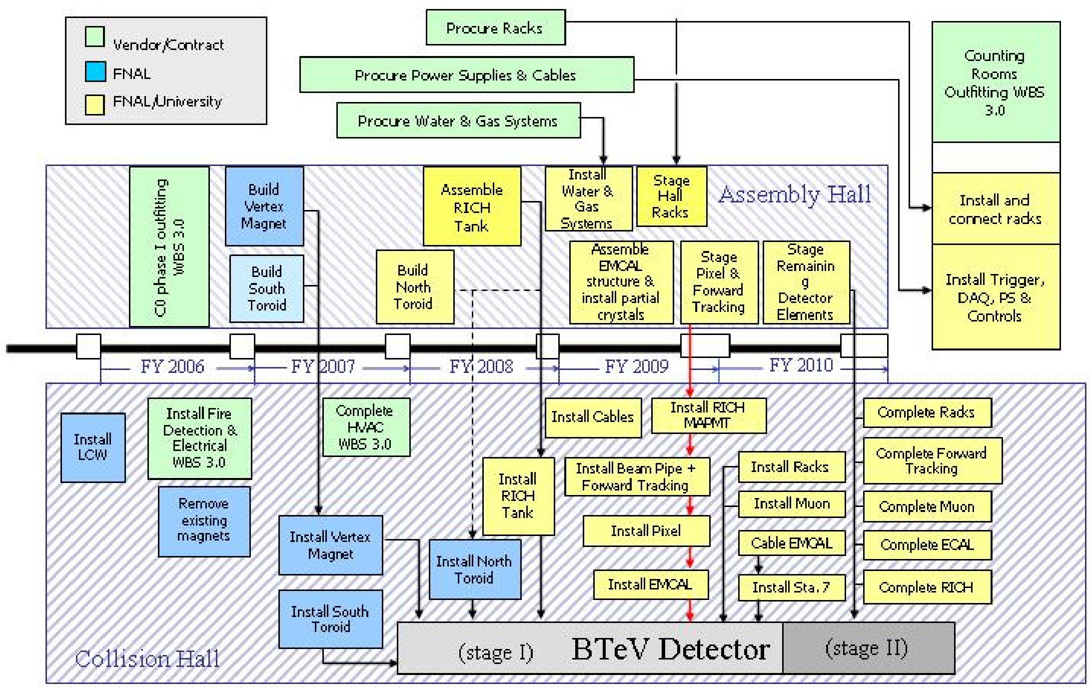


Figure 64: Flow diagram for Installation and Integration task (WBS 1.10)

A block diagram of the installation flow is shown in Figure 64. The installation details for the various subprojects that are addressed in this subproject are found in Installation, Integration and Testing Plan document prepared by each subproject. The plans include a narrative of the description of the steps involved with time, personnel and equipment required. They also contain data on numbers and type of cables and weights of components.

Installation activities at C0 will involve the installation activities for six large detector elements (three magnets, ECAL, RICH and tracking) and many activities for the installation of infrastructure, cables and racks. The most complicated installation activities will occur during the extended shutdowns with the installation of the pixel detector and the forward tracking straw and silicon strip detectors.

The first large elements to be installed will be the south (un-instrumented) toroid and the vertex magnet. Approximately one week is required to move, align and connect each one. These must be moved to the collision hall to clear the assembly hall for the assembly of the north toroid and the RICH detector tank. When ready, the north toroid can be installed in approximately one week. The vacated space in the assembly hall can then be used to assemble the ECAL support structure. The ECAL crystals can be installed both the assembly hall and the collision hall. The RICH will have mirrors and the Top PMT array mounted while in the assembly hall. The RICH tank will be installed during a short shutdown or an annual shutdown prior to an extended shutdown

The partially crystal loaded ECAL structure will be installed in the collision hall early in the first extended shutdown. The next elements to be installed will be the pixel tank and forward tracking. The pixel detector must be installed first followed by the forward tracking beam pipe. Once the Beam Pipe is installed and leak checked the forward tracking can be installed. The forward tracking straw and silicon strip detectors mount around the beam pipe and slide to the final mounting positions. Extensive cable and utility routing occurs as each forward tracking station is positioned. One RICH MAPMT will be installed before the Pixel detector and one will be installed after the forward tracking.

The first two Muon stations will be installed in a different work-zone of the collision hall while the Pixel and Forward Tracking installation proceeds. Loading of crystals in the ECAL structure can also proceed in parallel after straw station 7 is installed. Approximately 50% of the Trigger and DAQ will be installed with the majority of this work taking place in the counting rooms.

In the second extended shutdown, two additional straw stations and 3 strip stations will be installed to complete the forward tracking. The last Muon Station will be installed and the last three PMT arrays will be installed on the RICH detector. The remaining crystals will be loaded in to the EMCAL structure. The balance of Trigger and DAQ will be installed. The BTeV detector will be complete.

Figure 65 shows the labor profile (in FTE's) vs Fiscal Year for this subproject. The labor categories of scientists, engineers and technicians are listed in boxes by each bar. Table 32 and Figure 66 give the cost profiles for this project. The values in Figure 66 are shown without contingency. The values in Table 32 include contingency.

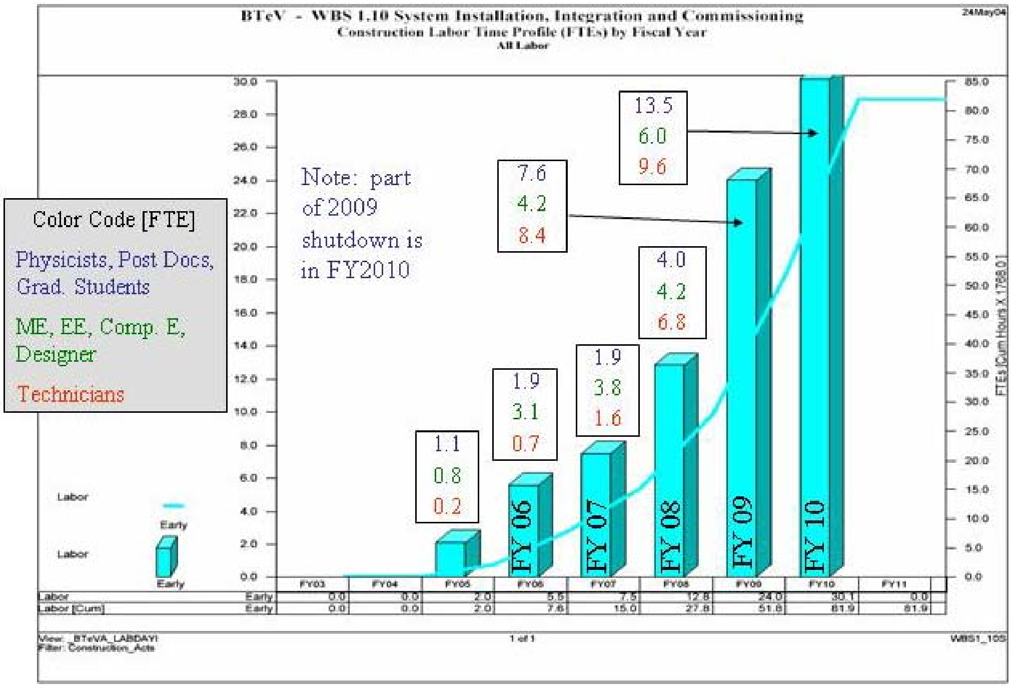


Figure 65: . Labor Profile (FTE) vs FY

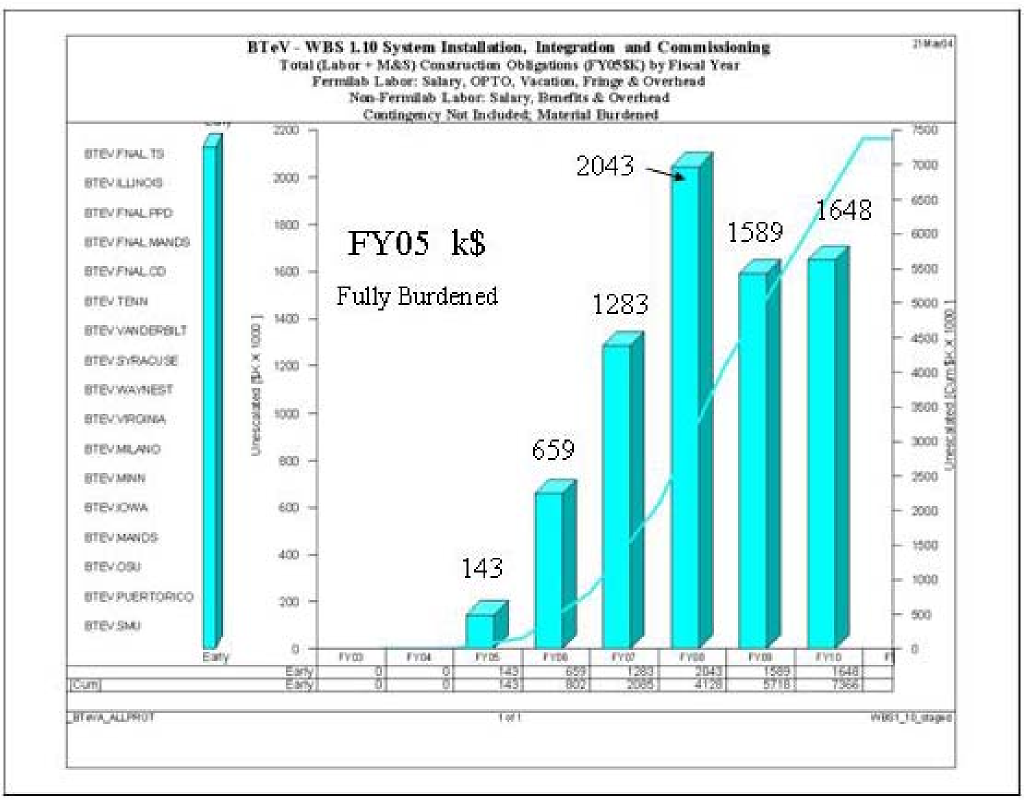


Figure 66: Cost (without contingency) vs FY

Activity ID	Activity Name	Material ($)	Labor($)	Base Cost ($)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.10.1	Installation Integration Testing and Commission Planning	0	433,745	433,745	0	121,765	142,288	296,810	26,191	0	587,054
1.10.2	Infrastructure Development Procurement InstallTest at C0	1,748,438	1,159,169	2,907,607	8,381	592,062	1,184,668	1,749,673	162,370	0	3,697,153
1.10.3	Component and Syst Transport Assembly Install and Connect	185,107	2,962,834	3,147,941	54,759	0	122,196	604,460	3,061,824	2,310,943	6,154,181
1.10.4	Multiple Subsys Interconnect and Int Testing at C0	29,000	560,712	589,712	0	0	0	0	0	1,350,442	1,350,442
1.10.5	System Integration and Testing	23,200	0	23,200	0	0	0	0	0	23,200	23,200
1.10.6	System Install Integrate Commission Subproject Management	48,794	441,577	490,372	127,916	129,955	170,601	150,216	0	0	578,687
1.1	**Subproject 1.10**	**2,034,539**	**5,558,037**	**7,592,576**	**191,057**	**843,782**	**1,619,752**	**2,801,158**	**3,250,384**	**3,684,585**	**12,390,717**

Table 32: : Total Cost vs FY

The Total Cost difference between the Lehman CD1 review and the current WBS is +$1,833k. The majority of cost differential arises from the implementation of the recommendation of the committee to increase contingency to 75%. The contingency is actually at 65% (an increase of $1,306K) but an additional $527K was added to the base primarily for labor that will be used between the extended shutdowns and during the 2nd extended shutdown.

Response to CD-1 recommendations.

- Develop schedule with adequate contingency using bottom-up information

The schedule uses labor and duration information provided by the sub-systems. The sub-systems have also re-evaluated their installation tasks and procedures and have eliminated un-necessary survey tasks and in some cases have increased the number of installation fixtures to speed installation.

- Using engineering design to decrease the installation duration.

This is an ongoing process. It involves developing the cable and utility routing details so that that field fitting is minimized. It involves evaluating detector design features that can speed installation and servicing. Finally it involves developing comprehensive CAD models of adjacent detectors to check for spatial conflicts.

- Appoint level 2 physicist for installation and integration

BTeV Project Management is actively seeking such a person.

- Increase installation contingency to 75%

The contingency is now 65% but the base costs were increased $522k because of additional labor applied before and during the second extended shutdown. The contingency was increased primarily in the installation labor portion of the sub-project.

7.11 Schedule for C0 Interaction Region (WBS 2.0)

7.11.1 Introduction

7.11.1.1 Brief Description

The C0 IR project will install an interaction region at C0 in the Tevatron. The Tevatron beamline will be modified from B43 to C17 (~450 meters). The major technical components are new LHC-type quadrupoles, new cryogenic spools containing correction magnets, electrostatic separators, power supplies for the previous 3 items, non-magnetic cryogenic elements, and supporting infrastructure changes including controls and instrumentation. The entire installation will be done in the 4 month shutdown starting 8/1/09.

Additionally, to allow staged installation of the BTeV detector, the C0 region of the Tevatron will be converted to a "normal" straight section in the 2 month shutdown starting 8/1/05.

7.11.1.2 Definition of Staged Detector

This is not a staged installation. The C0 IR will be installed during a single shutdown.

7.11.2 Project Flow & Cost

7.11.2.1 Key "Ready by" and "Need by" dates

	ID	Activity	Date	Float (days)	Duration (days)	Float/Dur. (%)
ready by	14.3.1	Lk4M: Quads ready for installation	12Dec08	200	1171	17
need by	14.4.1	Lk4M: Tunnel components needed	30Sep09			
ready by	14.3.2	Lk4M: Spools ready for	23Jan09	175	1197	15

		installation				
need by	14.4.1	Lk4M: Tunnel components needed	30Sep09			
ready by	14.3.3	Lk4M: 2005 shutdown preparations	23May05	52	120	43
need by	14.2.2	Lk3M: Begin FY05 Shutdown	08Aug05			
ready by	14.3.6	Lk4M: Ppwer Supplies ready for hookup	26Aug08	233	476	49
need by	14.2.14	Lk3M: Begin FY09 Shutdown	03Aug09			
ready by	14.3.8	Lk4M: Cryo components ready to install	01Oct08	208	760	27
need by	14.2.14	Lk3M: Begin FY09 Shutdown	03Aug09			
ready by	14.3.9	Lk4M: Controls ready to install	20May08	301	412	73
need by	14.2.14	Lk3M: Begin FY09 Shutdown	03Aug09			
ready by	14.3.10	Lk4M: Synch light monitor ready to install	23May05	22	190	12
need by	14.2.2	Lk3M: Begin FY05 Shutdown	08Aug05			
ready by	14.3.11	Lk4M: BPMs ready	15Sep05	240	240	100
need by	14.4.3	Lk4M: BPMs needed by	24Aug06			
ready by	14.3.12	Lk4M: Separators ready to install	19Dec08	194	560	35
need by	14.2.14	Lk3M: Begin FY09 Shutdown	03Aug09			
ready by	14.3.13	Lk4M: 2008 shutdown preparations ready	20May08	51	160	32
need by	14.2.11	Lk3M: Begin FY08 Shutdown	04Aug08			
ready by	14.3.15	Lk4M: 2007 shutdown preparations ready	20Apr07	73	100	73
need by	14.2.8	Lk3M: Begin FY07 Shutdown	06Aug07			
ready by	14.3.17	Lk4M: 2009 shutdown preparations ready	26Mar09	89	120	74
need by	14.2.14	Lk3M: Begin FY09 Shutdown	03Aug09			

Table 33: “Ready by” and “Need by” dates for IR project

The above table lists the 12 key “ready by” – “need by” floats for WBS2.0. In addition, the table lists the activity duration and float/duration. The standard BTeV calender is used – 5 days/week, with 11 holidays/year. The critical path item is 14.3.1 and the 2nd critical path item is 14.3.2. These are needed no later than 2 months after the start of the FY09 shutdown. Most other “need by” milestones are the start of shutdowns.

7.11.2.2 Project Flow

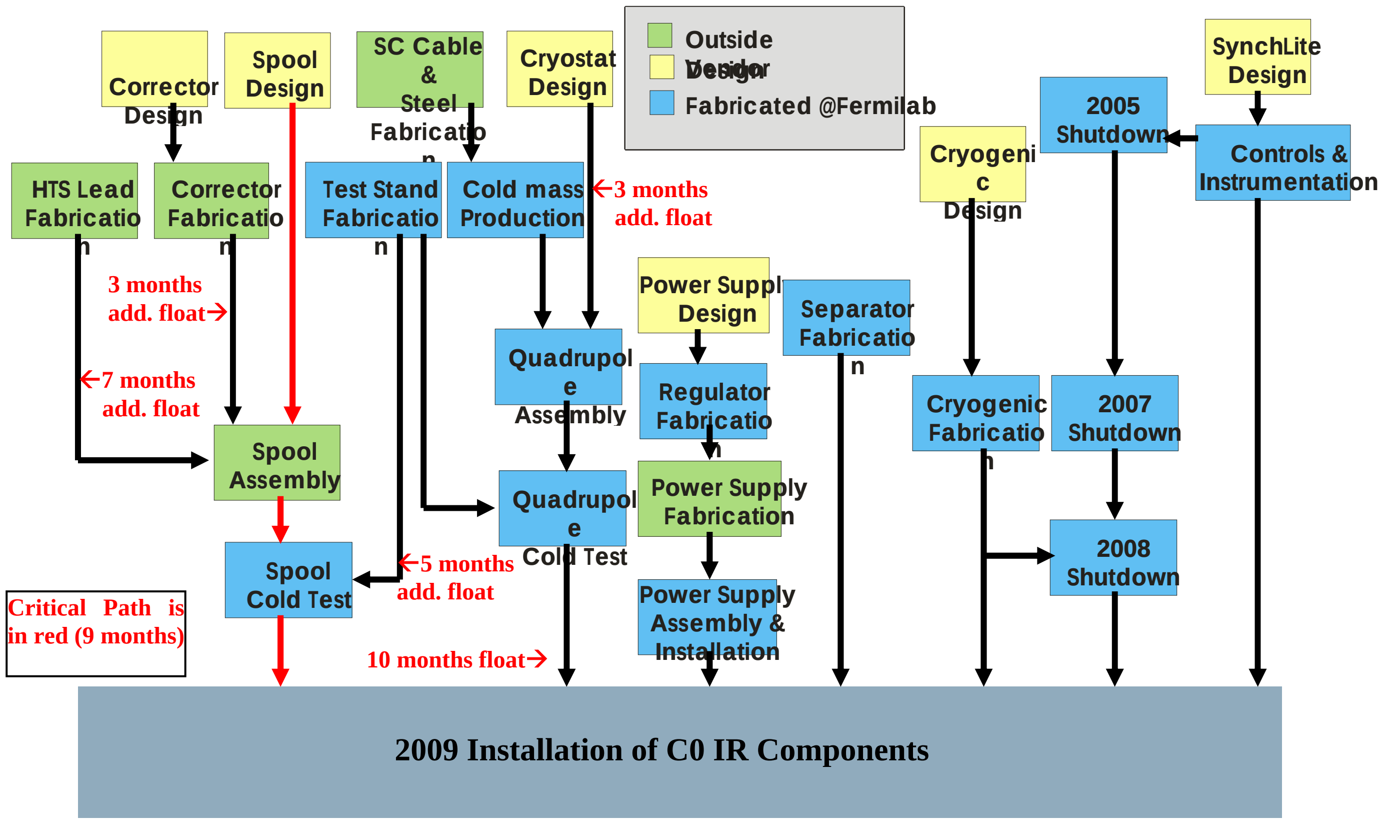
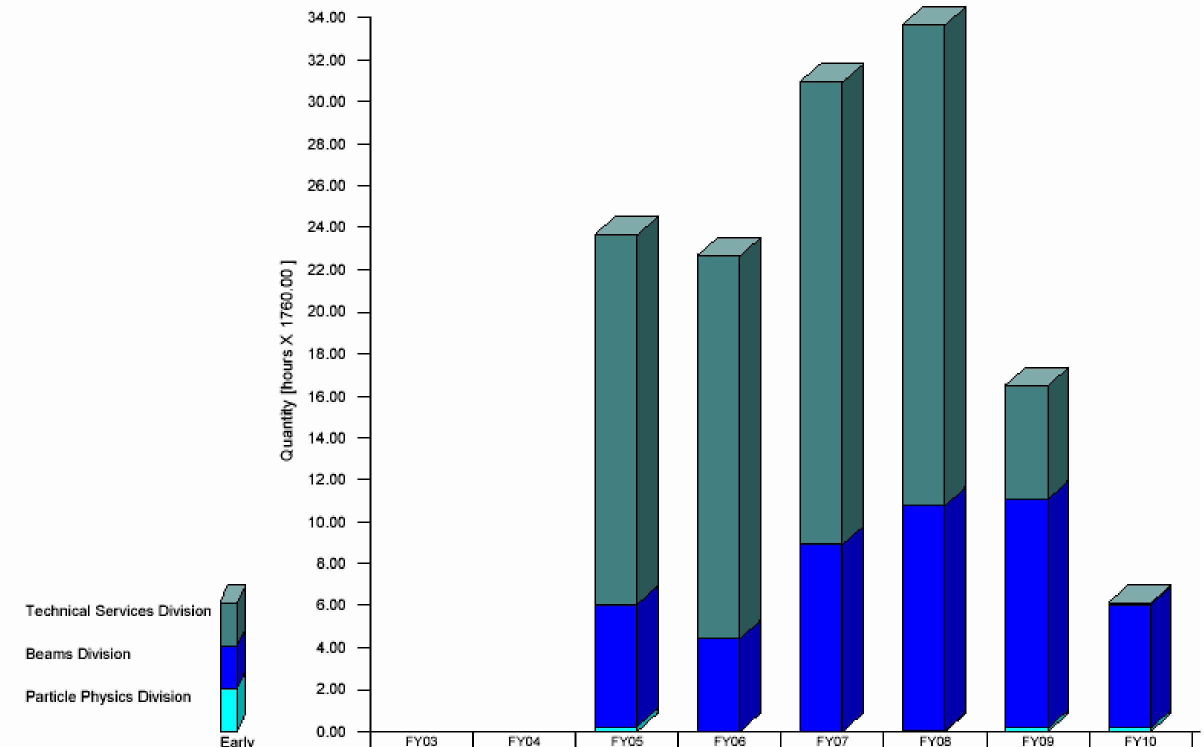


Figure 67: Project Flow for WBS2.0

The overall project flow is shown in Figure 67. Time flows from top to bottom. The critical path is shown in red and has a total float of 9 months. The next critical path item has a float of 10 months. Detailed discussion of critical paths is in section 7.11.2.5 below.

7.11.2.3 Labor Profile

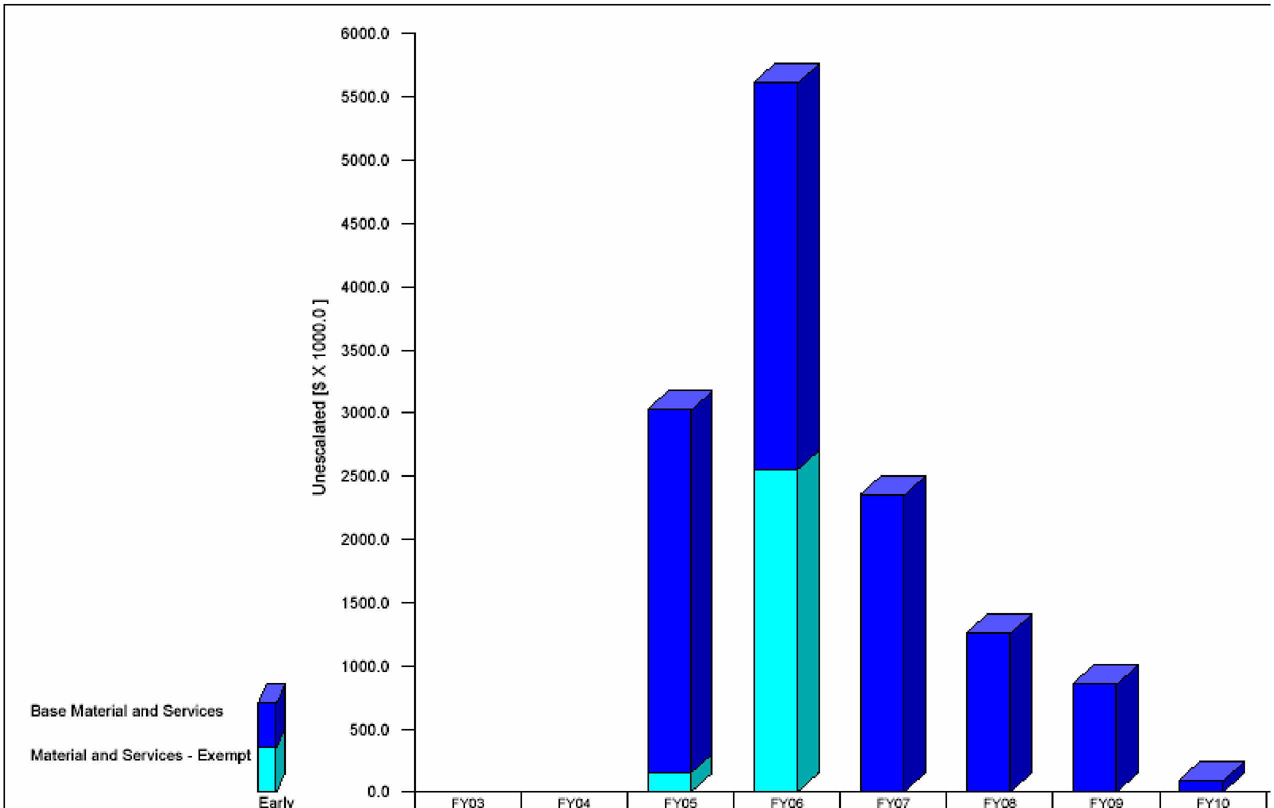


	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Particle Physics Division	0.00	0.00	0.19	0.00	0.00	0.05	0.14	0.15
Beams Division	0.00	0.00	5.82	4.41	8.90	10.68	10.89	5.86
Technical Services Division	0.00	0.00	17.58	18.21	21.96	22.90	5.44	0.09
change from CD-1 (FTEs) →			**+0.5**	**+0.7**	**-0.8**	**-1.8**	**-4.5**	**+6.1**

Figure 68: Labor Profile for WBS2.0

The labor profile is shown in `Figure 68`. Also listed is the change in profile from what was presented at the CD-1 review. There is a significant shift from FY09 into FY10 due to the delay in the FY09 shutdown schedule. In addition to the schedule changes, minor corrections, additions, and changes have been made to the WBS activities overall.

7.11.2.4 M&S Obligation Profile



	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Material and Services - Exempt	0.0	0.0	149.3	2538.7	0.0	0.0	0.0	0.0
Base Material and Services	0.0	0.0	2866.1	3061.1	2345.8	1252.0	848.6	85.8
change from CD-1 (K$) →			**-10**	**+746**	**-747**	**-346**	**+285**	**+86**

Figure 69: M&S Profile for WBS2.0

The M&S obligation profile is shown in `Figure 69`. Also listed is the change in profile from what was presented at the CD-1 review. There is a significant shift from FY07/8 into FY06/07 due to the change in spool fabrication schedule, and a significant shift from FY08 to FY09/10 due to the delay in the FY09 shutdown schedule. In addition to the schedule changes, minor corrections, additions, and changes have been made to the WBS activities overall.

7.11.2.5 Critical Path

Refer to the flow chart in section 7.11.2.2 for the following discussion.

The critical path item is the fabrication of the spools. It has 9 months of float. At the CD-1 review, this item was scheduled with 0 months of float. Where did the 9 months of additional float come from?

1) +2 months: Start of the FY09 shutdown on August 1, 2009.
2) +3 months: Delay of when the final non-spare spool is required to be installed with respect to the start of the shutdown by 2 months. The final spool is a spare and is not required until the end of the shutdown. Turnourand time for spool fabrication and test is 1/month.
3) +7 months: Shortening the procurement/contractual process for spool fabrication to 7 months. We intend to add more designers/engineers to the spool design up front. Positions have been opened in the Fermilab Technical Division for this purpose. An advanced design should shorten the contractual negotiations with vendors. 6 potential vendors have already been identified.
4) -3 months: Closer comparison of the spool fabrication schedule with the known DFBX fabrication schedule. DFBX are LHC cryogenic feed boxes currently being fabricated at a local vendor as part of the US contribution to the LHC project. We allow 12 months for fabrication and test of a prototype spool, and then 1 month/spool for each of 14 spools thereafter. A slippage of 2.8 weeks/spool (64%) would still allow us to make the schedule.

The corrector magnets are part of the spool assembly. At the CD-1 review the corrector magnets were presented as being on the critical path. We have shortened the procurement/contractual process for these items by 4 months (to 7 months). This is based on initial discussions with 4 other labs for the design and fabrication of these magnets. We already have detailed schedules from 2 of these labs, and our schedule is based on these submitted schedules. There is now an additional 3 months of float to the corrector path – ie., this activity would have to be delayed by greater than 3 months in order to impact the 9 month float in the spool delivery schedule.

After the spools, the next critical path is the quadrupoles, which now have 10 months of float. The schedule for the quadrupoles has not changed from what was presented at the CD-1 review. It is based on the LHC quad experience gained at Fermilab over the last 5 years. However, 5 months of float was gained from items 1) and 2) above. Both the new MTF test stand and the quad procurement/fabrication paths are critical. The next critical path for quadrupole production is the cryostat design, which has 3 months of additional float – ie., this activity would have to be delayed by greater than 3 months in order to impact the 10 month float in the quad delivery schedule.

7.12 Schedule for C0 Outfitting (WBS 3.0)

7.12.1 Introduction

7.12.1.1 Brief Description

The C0 Outfitting project installs the required structural, architectural, mechanical, fire protection, fire detection and electrical services for the construction and operations of the BTeV detector at the C-0 Building. In addition WBS 3.0 installs the architectural and electrical for WBS 2.0 IR.

7.12.1.2 Definition of Staged Work Packages

WBS 3.0 is complete well before the installation periods in 2009 and 2010. WBS 3.0 C0 Outfitting will be constructed under three major contracts. The phasing or staging of the work allows for the fiscal costs to be matched with available funds while still providing the spaces and services needed by the project. This is not a change from the CD-1 Review and is not related to the "staged scenario" introduced after the CD-1 review.

7.12.2 Project Flow & Cost

7.12.2.1 "Ready by" and "Need by" dates

	Act. ID	Activity Description	Early Start	Early Finish	Late Finish	Float
Ready By:	5.1	T5M: MS-1 Start Engineering	1-Oct-04	1-Oct-04		210d
Ready By:	5.2	T4M: MS-2 Start C0 Outfitting Construction	28-Jan-05	28-Jan-05		125d
Need By:	7.2.1	T2M: Start C0 Outfitting construction			1-Jun-05	125d
Ready By:	5.3	T5M: MS-3 Side Bay. Struct. Complete	17-Jun-05	17-Jun-05		157d
Ready By:	5.4	T5M: MS-4 Temo Power Operational (Fdr 45)	3-Feb-06	3-Feb-06		124d
Ready By:	5.5	T4M: MS-5 Beneficial occupancy of lower level and upper staging area	21-Dec-05	21-Dec-05		157d
Need By:	7.1.1	T1M: Occupancy: C0 low lvl, upper staging area			28-Jul-06	157d
Ready By:	5.6	T5M: MS-6 Collision Hall Complete	19-Mar-07	19-Mar-07		139d

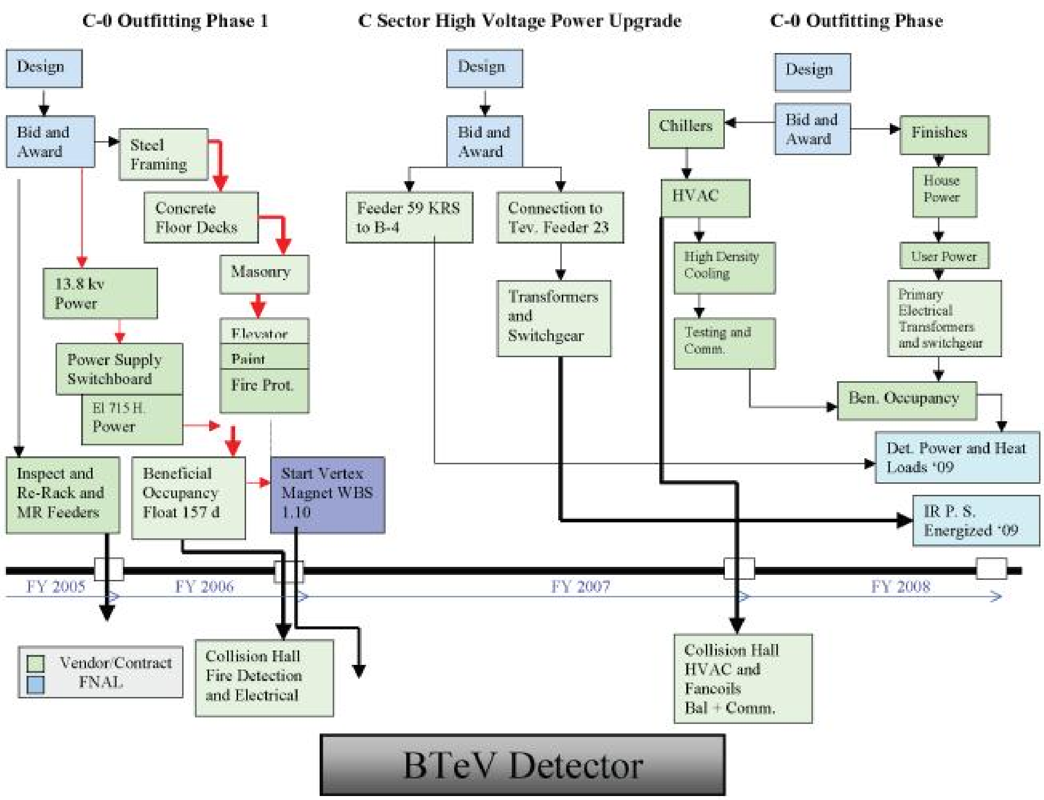
Need By:	7.3.3	T3M: Collision Hall completed			31-Jan-08	139d
Ready By:	5.7	T5M: MS-7 Mechancal Systems Complete (Except CH)	16-May-07	16-May-07		205d
Ready By:	5.8	T5M: MS-8 Electrical Systems Complete	21-Jun-07	21-Jun-07		179d
Ready By:	5.9	T4M: MS-9 Assembly, Service Building Construction Complete	21-Jun-07	21-Jun-07		179d
Need By:	7.3.4	T3M: Assy, Service Bldg construction completed			1-May-08	179d
Ready By:	5.1	T5M: MS-10 Engineering Complete	24-Aug-07	24-Aug-07		179d

Table 34: "Ready by" and "Need by" dates for C0 Outfitting

The Table 34 lists the nine key "ready by" – "need by" floats for WBS3.0. In addition, the table lists the activity early start and finish dates and float for pacing milestones leading to the key milestones. The standard BTeV calender is used – 5 days/week, with 10 holidays/year. The need by dates represent agreed upon dates with WBS 1.10, Infrastructure. See WBS 1.10 for the floats held within that sub-project.

7.12.2.2 Project Flow

Figure 70: Project Flow for C0 Outfitting, WBS 3.0



The overall project flow is shown in `Figure 70`. Time flows from top to bottom within each work package and left to right for the three work packages.

7.12.2.3 Labor Profile

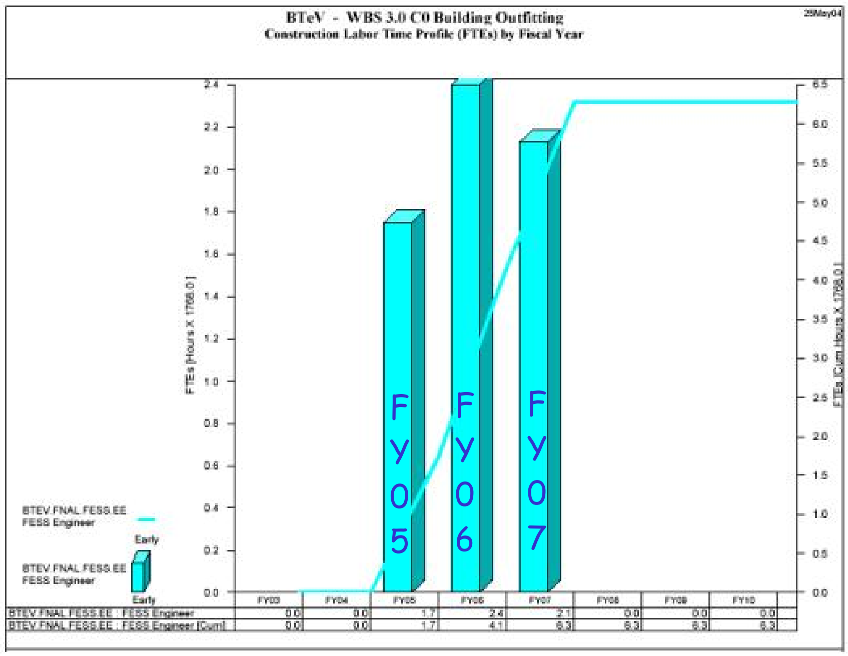


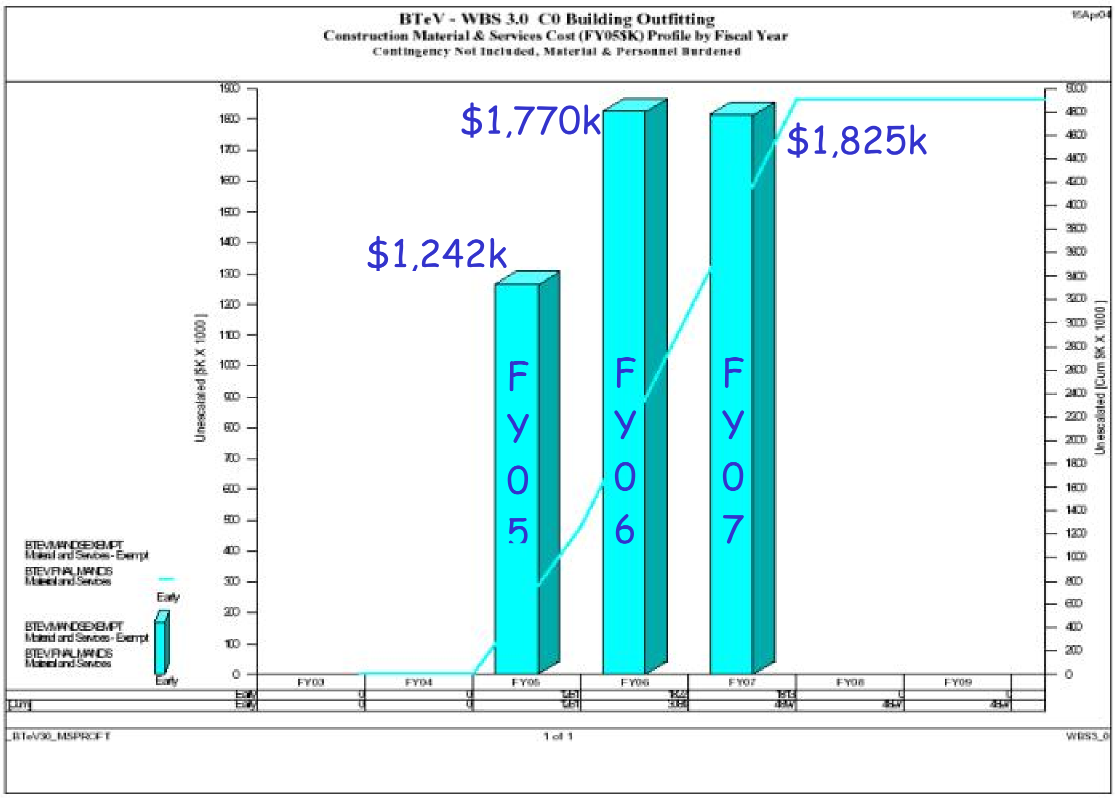
Figure 71: Labor Profile for C0 Outfitting, WBS 3.0

The labor profile is shown in `Figure 71`. Additional advanced conceptual design has the effect of lowering the FY 05 FTE requirements.

7.12.2.4 M&S Cost Profile

The M&S obligation profile is shown in Figure 72. The M&S costs are essentially the same as that shown in the CD-1 review.

Figure 72: M&S Profile for C0 Outfitting



7.12.2.5 Critical Path

Refer to the table in section 7.12.2.1 for the following discussion.

The increases in the float currently shown over those floats presented in the CD-1 review results from using the WBS 1.10, Infrastructure, "Need By" dates as the successors to the "Ready By" date to determine the floats for milestone activities. The "Need By" dates were established with concurrence of project management and WBS 1.10, Infrastructure management. The CD-1 review schedule mistakenly considered early "desired by" dates to calculate floats. The C-0 Outfitting schedule presented in the CD-1 review, while achievable, underestimated the allowable float that is available to successfully complete the project on time. The two critical scheduled elements "Phase 1 Complete" and " Ready By: Beneficial Occupancy of Lower Level and Upper Staging" have floats of 124 and 157 workdays respectively. The Beneficial Occupancy of Lower Level and Upper Staging allows the start of vertex magnet construction within the C0 Building. All work within the building will be completed at this time. The Phase 1 Complete includes the installation of the 13.8kv electrical service for the magnet power supplies that is required for testing of the completed magnet.

The type of contract work that is required to complete the C0 Outfitting Phase 1 work is basic to the construction industry and work commonly managed at Fermilab. Steel framing, concrete slab work and masonry comprise the majority of the scope. The work leading to the beneficial occupancy of the lower and upper staging areas is inside of the existing shell and not subject to weather related work stoppages. While material and labor issues could affect the schedule, it seems unrealistic that these effects could be in the 124 to 157 workdays range. The anticipated conceptual design effort will negate delays in the project start by two or three weeks, which can be absorbed without negatively affecting the schedule.

The C Sector High Voltage with 351 workdays of float, and the C0 Outfitting Phase 2 with 179 workdays of float allows for adequate schedule contingency. The type of trades involved with these contracts are also common to the construction industry and to Fermilab.

7.13 Schedule for BTeV Project Office (WBS 4.0)

The BTeV Project Office functions throughout the BTeV Project. The main impact of the staged schedule is that more technical staff must be retained through 2010 to manage the installation activities in the second stage of installation. Moreover, we have extended the clerical staff, including the budget officer, through 2010. This adds to the total cost of about $1.5M to the project cost and constitutes the major "standing army" effect connected with the staged schedule.

[1] See http://www-btev.fnal.gov/DocDB/0021/002115/011/index.shtml

[2] http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument?docid=3086&version=1~; the sensitivities have been updated for 396 ns bunch spacing.

[3] "LHCb Technical Proposal,'' CERN/LHCC 98-4, LHCC/P4 (1998), available at http://lhcb.cern.ch ~.

[4] LHCb has recently recognized this flaw in their design. They have removed the shielding plate on their magnet and now have a magnetic field between 50 and 260 Gauss on their vertex detector. Unfortunately this also puts 250-1000 Gauss on their first RICH detector, which causes the tracks to bend while traversing the gas radiator and we believe will significantly deteriorate the resolution. It also makes it very difficult to shield the HPD photon-detectors see "LHCb Addentum to the LHCb RICH TDR, {\it Photon Detectors for the LHCb RICH}," CERN/LHCC 2003-59.

[5] The BTeV electromagnetic calorimeter is superior in energy resolution and segmentation to LHCb's. LHCb has a Shaslik-style Pb-scintillating fiber device, following a preshower detector. The LHCb energy resolution is $10\%/\sqrt{E} \oplus 1.5\%$, which compares poorly with BTeV's $1.7\%/\sqrt{E} \oplus 0.55\%$. The LHCb detector segmentation is 4 cm x 4 cm up to \sim90 mr, 8 cm x 8 cm to \sim160 mr and 16 cm x16 cm at larger angles. (The distance to the interaction point is 12.4 m.) Thus the segmentation is comparable to BTeV only in the inner region. (BTeV has 2.8 cm x 2.8 cm crystals 7.4 m from the center of the interaction region.)

[6] P. Collier, "Running in the LHC, Part I Summary of Session 7," presented at LHC Project Workshop - Chamonix XIII (2003); can be found at http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument?docid=3062\&version=1

[7] Projections of integrated Tevatron luminosity in the BTeV era as presented by M. Witherell to the BTeV CD-1 Review; can be found at http://www-btev.fnal.gov/DocDB/0030/003018/001/BTeV%20DOE%20review%2004-04%20intro.pdf .

[8] BTeV will have a beam crossing interval that at 396 ns bunch spacing is 15.8 times longer. In fact, LHCb's plan is to trigger in their first trigger level on muons, electrons or hadrons of moderate p_t, and detect detached vertices in the next trigger level. For two-body decays, they now believe only the p_t trigger is sufficient.

[9] See reference 3

[10] P. Ball et al. , "B decays at the LHC," CERN-TH/2000-101 [hep-ph-0003238].

---

[11] LHCb Technical Design Report, Reoptimized Detector Design and Performance, CERN/LHCC 2003-030, LHCb TDR 9 (2003).

[12] See T. Nakada, "LHCb Light status and related issue," at http://lhcb-doc.web.cern.ch/lhcb-doc/progress/progress.htm .

[13] P. Collier, "Running in the LHC, Part I Summary of Session 7," presented at LHC Project Workshop - Chamonix XIII (2003); can be found at http://www-btev.fnal.gov/cgi-bin/DocDB/ShowDocument?docid=3062\&version=1

[14] The calculation uses $2.8 \times 10^{32} cm^{-2} s^{-1}$ for 139 days with a machine efficiency that includes the fall off of the luminosity with time, filling etc. of 24%.

[15] See 7 for reference

[16] R. Bailey, "Machine Commissioning: 1st Collisions to 10^{33}," in proceedings of Chamonix XII, CERN-AB-2003-008 ADM, March 2003; J. Virdee, "Requirements from the Experiments in Year 1," ibid. Both can be found at http://ab-div.web.cern.ch/ab-div/Conferences/Chamonix/chamx2003/contents.html~.

[17] The actual amount of commissioning time for the detectors is a complicated issue. BTeV has the advantage of being able to run some parts of the detector using a wire target before the 2009 installation. Plans exist for a test of the magnet 10% of the pixel system, some straw planes for tracking, the prototype L1 trigger and one DAQ highway. LHCb, on the other hand, will have access to their detector limited by machine tuning, and the desire of the larger ATLAS and CMS groups to keep running.

[18] See reference 1

[19] see ref. 11

[20] B. Aubert et al., (Babar) [hep-ex/0308035]; K. Abe et al., (Belle) [hep-ex/0403026];

[21] see reference 1

[22] LHCb Technical Design Report, Reoptimized Detector Design and Performance, CERN/LHCC 2003-030, LHCb TDR 9 (2003).

[23] See reference 2

[24] The CDF and D0 signals in the $J/\psi\phi$ mode were shown by P. Makismovic, "CP Violation Prospects at the Tevatron," presented at Beauty 2003, see http://www-hep.phys.cmu.edu/beauty2003/ ; the sensitivity to χ is estimated by taking the total Run II integrated luminosity between 4.4 and 8.6 fb^{-1}, a flavor tagging efficiency between 5-10% and a time resolution and signal to background the same as the LHCb projection.